STUDIES IN SPORT, PHYSICAL EDUCATION AND HEALTH

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Nina Nevala-Puranen

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Effects of Occupationally Oriented Medical Rehabilitation and Environmental Measures

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UNIVERSITY OF JYVÄSKYLÄ

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ABSTRACT

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Diss.

The aim of this study was to assess the effects of occupationally oriented medical rehabilitation and environmental measures on dairy farmers' physical work and ergonomics. This aim was attained with 5 studies. The physical load, strain, and work pace of milking in 2 types of cowhouses were quantified in 2 studies, the effect of occupationally oriented medical rehabilitation on farmers' work techniques, musculoskeletal pain and perceived work ability were assessed in 2 studies, and 1 study described the physical strain of farmers with physical disabilities. In the studies, the number of subjects (aged 26-53 years) varied between 4 and 95. Machine milking was light or moderate work for the cardiorespiratory system both in the tie stalls and in the parlors. Bent and twisted back postures accounted for 29% of milking time in the tie stalls without a rail system, 10% in the tie stalls with a rail system, and 1% in the parlors. Work postures with one or both arms at or above shoulder level were more typical in the parlors than in the tie stalls. However, the muscle activity of shoulder muscles was 2-8% of the maximal voluntary contraction in parlor milking. The use of a rail system in the tie stalls decreased the proportion of harmful back postures and increased work pace compared with milking without a rail. Occupationally oriented medical rehabilitation courses, lasting 3 weeks and organized in rehabilitation centers, changed the farmers' work techniques during a 1-year follow-up. Farmers worked with a bent or twisted back less often after 1 year when compared with the prerehabilitation situation. Training in lifting techniques did not decrease the biomechanical load of the back when sacks of 20 or 30 kg were lifted. The subjects had less musculoskeletal pain and better work ability at the end of the follow-up than before the rehabilitation. The mean aerobic strain of the farmers with physical disabilities (leg amputation, paraplegia) was mainly light or moderate during work. Impossible work tasks due to the disability were milking, handling of heavy materials, transferring of animals, operating and repairing tasks, and forestry work. Occupationally oriented medical rehabilitation courses and environmental measures proned to be feasible ways to develop ergonomics in dairy farmers.

Key words: agriculture, disability, ergonomics, heart rate, oxygen consumption, physical strain, rehabilitation, work posture

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Kuopio, May 1997
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LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following articles, which are referred to in the text by their Roman numerals:

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II. Nevala-Puranen N, Kallionpää M, Ojanen K. Physical load and strain in parlor milking. International Journal of Industrial Ergonomics 1996; 18: 277-282.

III. Nevala-Puranen N. Reduction of farmers' postural load during occupationally oriented medical rehabilitation. Applied Ergonomics 1995; 26: 411-415.

IV. Nevala-Puranen N. Effects of occupationally-oriented rehabilitation on farmers' work techniques, musculoskeletal symptoms, and work ability. Journal of Occupational Rehabilitation 1996; 6: 191-200.

V. Nevala-Puranen N, Sörensen L. Physical strain and work ergonomics in farmers with physical disabilities. International Journal of Occupational Safety and Ergonomics (in press).

ABBREVIATIONS

BMI	=	body mass index
2D	=	two-dimensional
ECG	=	electrocardiography
EMG	=	electromyography
HR	=	heart rate
HRmax	=	maximal heart rate
HRmean	=	mean heart rate
HRrest	=	resting heart rate
%HRmax	=	percentage of the maximal heart rate
%HRR	=	percentage of the heart rate range
L5/S1 disc	=	the intervertebral disc between the 5th lumbar vertebra and the sacrum
MVC	=	maximal voluntary contraction
%MVC	=	percentage of maximal voluntary contraction
OWAS	=	Ovako Working posture Analysing System
OWASAN	=	OWAS analyzing program
OWASCO	=	OWAS collection program
RPE	=	rating of perceived exertion
VAS	=	visual analogue scale
VO_2	=	oxygen consumption
VO_2max	=	maximal oxygen consumption
$\%VO_2max$	=	percentage of maximal oxygen consumption
WAI	=	work ability index
WHO	=	World Health Organization
WOPALAS	=	Working Posture Analysing System

CONTENTS

1 INTRODUCTION

The structural change in agriculture continues in Finland as it makes its place as a member of the European Union. The number of farmers has decreased during the last several years, and many small farms have stopped production. In 1994 there were 96 000 farms and 89 000 male and 61 000 female farmers, two-thirds of whom worked full-time (Farmers' Social Insurance Institution 1995). Agricultural production consists of dairy farming, animal husbandry, production of grain and other crops, and forestry. The most common farm operation is still dairy farming (40 000 farms) where milking constitutes a major part of the daily work.

In Finland, almost half of the male farmers (48%) and 59% of the female farmers are over 45 years of age (Susitaival 1994), the retirement age of farmers being 65 years. Musculoskeletal disorders cause the most work disabilities of farmers (Gustafsson et al. 1994, Manninen & Notkola 1994, Hildebrandt 1995, Manninen 1996), who are also at increased risk of accidents (Cogbill et al. 1991, Merchant 1991, Belville et al. 1993). Several epidemiological studies have shown the association between the musculoskeletal disorders and the physical load factors of farmers' work (Penttinen 1987, Gustafsson 1990, Gustafsson et al. 1994, Hildebrandt 1995, Stål et al. 1996).

Farmers' work varies according to the farm operation and the level of mechanization. The work environment of the farm is diverse, including barns, sheds, grain enclosures, silos, fields, and forests (Cordes & Rea 1991). Manual materials handling, poor work postures, repetitive movements, and vibration are typical load factors in all farm operations (Lundqvist 1988, Nemeth et al. 1990, Hildebrandt 1995).

Ergonomic measures in agriculture are accentuated due to physical load factors, the large number of female workers, ageing, musculoskeletal disorders, and permanent physical impairments (Ahonen et al. 1990, Engberg 1993, Gustafsson et al. 1994, Susitaival 1994, Meyers et al. 1995, Stål et al. 1996). Studies of rehabilitation and environmental measures carried out in agriculture have concentrated on the primary (Arborelius et al. 1986, Klen et al. 1991, Hagen 1993), secondary (Väyrynen & Könönen 1991, Perkiö-Mäkelä 1996), and tertiary (Petrea et al. 1996) prevention of musculoskeletal disorders. By 1992, 45% of all full-time farmers had joined the voluntary farmers' occupational health services, which aim to promote farmers' health by checking their work conditions, organizing health checks, and providing information and recommendations (Susitaival 1994).

In the future, there will be fewer farmers, larger farms and a higher level of mechanization in comparison with the current situation in Finland. Dairy farms will presumably remain the most common type of farm. Higher production with optimized work loads require efficient utilization of ergonomic measures.

The aim of this study was to assess the effects of occupationally oriented medical rehabilitation and environmental measures on dairy farmers' physical work and ergonomics. This objective was attained with 3 case studies and 2 intervention trials. The physical load, strain, and work pace were analyzed during milking in different types of mechanized environments (I, II); the effects of occupationally oriented medical rehabilitation on farmers' work techniques, musculoskeletal pain, and work ability were evaluated (III, IV); and the physical strain was analyzed among farmers with physical disabilities (V).

2 REVIEW OF THE LITERATURE

2.1 Theoretical framework of the study

The stress-strain model developed by Rutenfranz (1981) for heavy dynamic muscle work was used as a theoretical framework for this study. The model analyzes factors associated with a person's strain at work, which depends both on the stress (load) factors of work and on individual characteristics and abilities (Figure 1). The stress-strain relationship can be either suitable or unsuitable to health and work ability (Ilmarinen et al. 1991b, Tuomi et al. 1991a). The stress-strain model has been described and used as a theoretical model in several occupational studies (Rohmert 1982, 1984, Suurnäkki et al. 1991, Tuomi et al. 1991b, Lusa 1994, Louhevaara 1995).

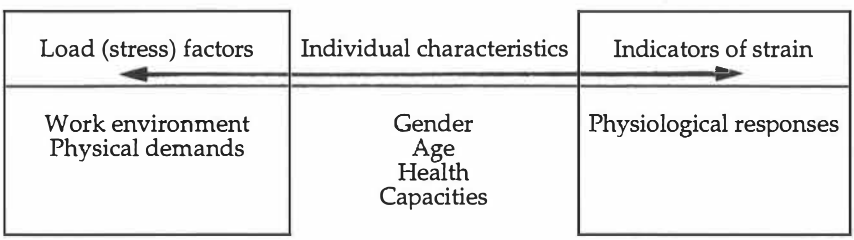

FIGURE 1 Modified stress-strain model (Rutenfranz 1981)

2.2 Assessment of physical work load and strain in agriculture

In agricultural studies (including forest work) several methods have been used to quantify the physical load and strain of work (Table 1). Most of these studies have been carried out in habitual work situations (Kukkonen-Harjula & Rauramaa 1984, Costa et al. 1989, Ahonen et al. 1990, Lundqvist 1990, Klen et al. 1991, Väyrynen & Könönen 1991, Hagen 1993, Kirk & Parker 1996) and the biomechanical studies have been performed in laboratories (Ekholm et al. 1985, Svensson et al. 1985, Arborelius et al. 1986, Nemeth et al. 1990, Hagen 1993).

In a few studies (Kukkonen-Harjula & Rauramaa 1984, Ahonen et al. 1990, Klen et al. 1991) the mean oxygen consumption (VO_2) and heart rate (HR), measured in work situations, have been proportioned to the maximal oxygen consumption (VO_2max) and maximal heart rate (HRmax) as measured in maximal exercise tests with direct respiratory gas analyses in a laboratory. The mean VO_2 and HR values during work have also been proportioned to the estimated VO_2max with submaximal exercise tests and the age-specific HRmax values (Costa et al. 1989, Hagen et al. 1993, Kirk & Parker 1996).

The musculoskeletal load and strain have mainly been analyzed from work postures with the Ovako Working posture Analysing System (OWAS) and Working Posture Analysing System (WOPALAS) methods in actual work situations or with electromyography (EMG) measurements in simulated work tasks.

TABLE 1 Methods used to assess physical work load, individual characteristics and strain in agricultural studies

Characteristic	Method	Reference
Load factors		
* VO_2 and/or ventilation	Portable measuring device	Kukkonen-Harjula & Rauramaa (1984), Costa et al. (1989), Ahonen et al. (1990), Klen et al. (1991), Gite (1993), Hagen et al. (1993)
* Work postures	OWAS	Väyrynen & Könönen (1991), Klen et al. (1991), Kivikko (1996), Scott & Lambe (1996)
	WOPALAS	Lundqvist (1990), Pinzke (1996)
* Biomechanical load	Calculations from photographs	Ekholm et al. (1985), Svensson et al. (1985), Arborelius et al. (1986), Nemeth et al. (1990)
	2 D Static Strength Prediction Program	Hagen (1990), Jorgensen et al. (1990), Hagen (1993)
Individual characteristics		
* Cardiorespiratory capacity	Maximal exercise tests with respiratory gas analyses	Spurr et al. (1977), Kukkonen-Harjula & Rauramaa (1984), Ahonen et al. (1990), Klen et al. (1991)
	Submaximal exercise tests without respiratory gas analyses	Hagen et al. (1993), Mamansari & Salokhe (1996)
* Musculoskeletal capacity	Maximal voluntary contraction (MVC)	Ekholm et al. (1985), Svensson et al. (1985), Arborelius et al. (1986), Nemeth et al. (1990)
* Musculoskeletal symptoms	Questionnaires	Stål & Pinzke (1991), Gustafsson et al. (1994), Hildebrandt (1995), Manninen et al. (1995), Perkiö-Mäkelä (1996), Stål et al. (1996)
* Work ability	Work ability index (WAI)	Perkiö-Mäkelä (1996)
Indicators of strain		
* HR	Electrocardiography (ECG)	Costa et al. (1989), Klen et al. (1991)
	Telemetric measurements	Kukkonen-Harjula & Rauramaa (1984), Gite (1993), Hagen et al. (1993), Kirk & Parker (1996)
* Muscle activity	EMG	Ekholm et al. (1985), Svensson et al. (1985), Arborelius (1986), Nemeth et al. (1990), Klen et al. (1991)
* Perceived exertion	Rating of perceived exertion (RPE)	Costa et al. (1989), Ahonen et al. (1990), Gite (1993), Hagen (1993)

2.3 Physical load in farmers' work

2.3.1 Work environment

Farmers regard air quality, noise and vibration as the most serious environmental problems in their work (Lundqvist 1988). According to Farrar et al. (1995) three-fourths of farmers consider injuries to be the most important concern in their work. However, Hildebrandt (1995) found that farmers report less exposure to poor climatic conditions and vibration than referents in other, nonsedentary occupations.

Women have traditionally taken care of cattle and milking, while men have worked more in the fields and forests. According to Lundqvist (1988) and Stål & Pinzke (1991) dairy farmers work over 40 hours per week, 7 days a week, all year with few vacations. The temperature, lighting, and relative humidity vary greatly in the barns (Lundqvist 1988, Linnainmaa et al. 1993). Warm barns have been the most common type barn on dairy farms, but the number of cold production buildings has also increased during the last several years (Tuure 1995).

In Finland, most barns are tie stalls and according to statistics on the rail systems and milk stations sold, about 1 100 rail systems and 1 000 milking parlors were in use in Finland by 1996. In machine milking, the vertical difference in floor levels and the horizontal distance between the cows and the milker are the important environmental factors mainly affecting musculoskeletal load (Vos 1974, Arborelius et al. 1986, Nemeth et al. 1990).

The use of machines and work tools depends on the level of farm mechanization. Particularly in the transfer of loads, the utilization of carts and machines decreases the manual materials handling in several work phases (Kivikko 1993). In Finland, especially the storing of hay and a manure deleting system have been developed during the last 15 years (Susitaival 1994). The shape and weight of agricultural work tools have been shown to be connected with the physical load and strain (Gite 1993, Hagen 1993).

Farmers are exposed to whole-body vibration when driving a tractor. In different farm operations most vibration has been reported in agricultural contract work, fruit farming and dairy farming (Hildebrandt 1995).

The risk for injury in farm work results mainly from the work environment or work with machinery or animals (Cogbill et al. 1991, Merchant 1991, Farmers' Social Insurance Institution 1995), and the majority of injuries occur on dairy farms (Belville et al. 1993). Merchant (1991) reported agricultural machinery to be associated with 48% of injuries leading to a permanent impairment. Work environment factors cause injury risks especially for disabled farmers (Field & Tormoehlen 1985). Regular use of other persons to complete certain work tasks, especially around machinery, and fire in the work environment are threats to the disabled persons. Machine vibration and sudden movements of animals can cause uncontrolled muscle contractions for paralyzed workers who suffer from spasticity. Visual impairments make color and depth perception difficult, and hearing impairments hinder the detection of machine failures. Muscle fatigue due to the use of one arm or leg also increases the risk of accident.

2.3.2 Physical demands

Cardiorespiratory load

Cardiorespiratory (i.e., dynamic) work load can be objectively described with the measurement of absolute oxygen consumption (VO_2, $l \cdot min^{-1}$) or by calculating energy expenditure ($kJ \cdot min^{-1}$, $kcal \cdot min^{-1}$) using the VO_2 value ($1\ l \cdot min^{-1}\ O_2 = 20.17\ kJ \cdot min^{-1} = 4.825\ kcal \cdot min^{-1}$).

VO_2 has been measured in motor-manual cutting (felling, limbing and bunching) among 15 younger (mean age 29 years) and 16 older (mean age 59 years) loggers. The VO_2 for all work phases was 1.8 $l \cdot min^{-1}$ for the younger loggers and 1.5 $l \cdot min^{-1}$ for the older ones (Hagen et al. 1993). Kukkonen-Harjula & Rauramaa (1984) reported that the VO_2 was 1.8-1.9 $l \cdot min^{-1}$ in felling, limbing and bunching, the highest work load (2.2 $l \cdot min^{-1}$) occurring in bunching. Klen et al. (1991) compared 2 different work methods (n=5) during the debranching of trees. The VO_2 varied between 1.6 and 2.9 $l \cdot min^{-1}$ when the traditional (clean cutting) method was used and between 1.6 and 2.8 $l \cdot min^{-1}$ when Kilk's method was chosen (the saw being supported as much as possible against the trunk of the tree).

Musculoskeletal load

Musculoskeletal load can be quantified by work postures, biomechanical load (N, Nm), and muscle activity (µV). High static postural load is typical in agriculture and forest work (Lundqvist 1988, Lundqvist 1990, Klen et al. 1991, van Dieen & Hildebrandt 1991, Hildebrandt 1995, Scott & Lambe 1996), and load on the back is highest in dairy farming, arable farming, beef production, mushroom production, outdoor vegetable growing, fruit growing, and arboriculture (van Dieen & Hildebrandt 1991). Lundqvist (1988) reported that milking in tie stalls involved poor work postures during 38% of the milking time compared with 9% in parlor milking. He found the largest postural load during the handling of ensilage and hay and the shoveling of manure on farms with a low level of mechanization.

Lundqvist (1990) and Scott & Lambe (1996) evaluated the postural load in a perchery system. Loading work postures of the back and legs were found especially when eggs were collected from the floor and when birds were collected. In the debranching of trees (Klen et al. 1991) the use of the new "Kilk's method" required fewer bent and twisted back postures than the traditional work method. The muscle activity in the shoulders (m. trapezius) ranged from 24 to 68 µV and in the back (m. erector spinae) from 55 to 87 µV when either the traditional or Kilk's method was used.

The loading moment (Nm) of 20 different work postures of milking was measured for different body parts in the laboratory (Ekholm et al. 1985, Svensson et al. 1985, Arborelius et al. 1986, Nemeth et al. 1990). The shoulder and ankle joints were less loaded at a 0 or 0.2 m level difference between the milker and the cow when the milker's knees were straight (Svensson et al. 1985, Arborelius et al. 1986). For the knees, the lowest load occurred with the 0.5 m level difference and working with bent knees (Ekholm et al. 1985). The load on the low back ranged between 64 and 170 Nm. The lowest induced lumbar load occurred with a vertical level difference of 0.9 or 1.0 m between the milker and the cow. The lowest load of the hip was also measured at the level difference of 1.0 m (Nemeth et al. 1990).

Hagen (1990) used biomechanical modeling to estimate back compression in the felling phase of forest work. The static back compression was 6681 and 4719 N during work with straight or bent knees, respectively.

2.4 Health and work ability of farmers

Farmers consider their work ability to be poorer than workers in other occupations in Finland, and the work ability decreases with age the most frequently for female farmers (Perkiö & Notkola 1994). However, the risk of retirement before the age of 55 years is lower for farmers than for other Finnish populations (Manninen & Notkola 1994).

Musculoskeletal disorders cause most of the work disabilities of farmers, for example, in Finland (Manninen & Notkola 1994), Sweden (Gustafsson et al. 1994) and The Netherlands (Hildebrandt 1995). The most prevalent musculoskeletal symptoms are low-back and neck-shoulder pain (van Dieen & Hildebrandt 1991, Gustafsson et al. 1994, Hildebrandt 1995, Manninen et al. 1996a), and the symptoms are the most common in farmers over 45 years of age (Gustafsson 1990, Gustafsson et al. 1994, Manninen et al. 1996a). Dairy farmers in Sweden have more musculoskeletal symptoms in the neck, shoulders, elbows, wrists, hands, lower back, hips and knees than referents from other occupations (Gustafsson 1990, Gustafsson et al. 1994, Stål et al. 1996).

Farmers' low-back pain has been shown to be associated with manual materials handling, stooping postures, and motor vehicle driving (Penttinen 1987, Gustafsson et al. 1994). Farmers' neck and shoulder symptoms are related to the repetitiveness of static posture exposure, for example, the number of milking units (Gustafsson 1990, Gustafsson et al. 1994) or postures with arms over the shoulder level (Sakakibara et al. 1995). According to Stål et al. (1996) active milkers report pain and discomfort in their wrists and hands significantly more often than nonmilkers, but not in their neck, shoulders or elbows. However, shorter milkers experience significantly more symptoms in the shoulders than do taller milkers. Hip joint disorders among farmers are possibly caused by cumulative mechanical stress from heavy lifting, vibration, and walking over rough ground (Vingard et al. 1991, Croft et al. 1992a, 1992b), and osteoarthritis in the knee is associated with age, female gender, overweight and heavy work (Manninen et al. 1996b).

Manninen & Riihimäki (1994) found no differences in musculoskeletal symptoms between different farm operations. However, van Dieen & Hildebrandt (1991) and Hildebrandt (1995) reported that symptoms of the low back are the most prevalent in pig production, bulb growing and arboriculture. Neck-shoulder symptoms occurred more often in protective vegetable growing and arboriculture than in other farm productions, and symptoms of the elbows and wrists or hands appeared more often in fruit farming and arboriculture (Hildebrandt 1995). The same study also showed that the symptoms were localized in the dominant body parts, indicating asymmetrical exposure of the arms and hands.

A low incidence of cardiovascular diseases has been found for farmers (Thelin 1991, Hammar et al. 1992). Fresh air, physical activity at work, reduced tension and living pace and stable social circumstances (Cumming & Bailey 1974, Salonen et al. 1988, Berlin & Colditz 1990, Thelin 1991), combined with less smoking and a low prevalence of hypertonia (Thelin 1991, Hammar et al. 1992, Susitaival 1994), have been reported as the possible reasons. However, overweight is more typical among farmers than in other occupational groups of women but not men in Finland (Perkiö & Notkola 1994). Eaton et al. (1994) and Helakorpi et al. (1996) reported less physical exercise during leisure time for farmers than for other occupational groups. According to Mälkiä (1983) persons living in a rural area have better grip force, and women have better back endurance force than persons living in towns.

Several studies have shown that farmers have a generally low cancer morbidity (Notkola et al. 1987, Thelin 1991). Mental symptoms have been shown to be equal between farmers and referents in Finland (Susitaival 1994), but fewer among farmers than among referents in Sweden (Thelin 1991). Farmers have work-related respiratory symptoms more often than referents (Susitaival 1994). According to Susitaival (1996) hand dermatoses among dairy farming women are twice as prevalent as among farmers engaged in other farm operations or workers in other occupations.

Amputations account for 0.4% of all agricultural injuries in Finland (Farmers' Social Insurance Institution 1995). Field (1989) found that, in the United States, 2% of all farm injuries are amputations. Cogbill et al. (1991) reported that, during a 12-year period, anatomic or functional loss of an entire limb or a part of a limb was recorded for 18% of the patients admitted to a trauma center as the result of farm injuries in the United States.

2.5 Physical strain in farmers

Cardiorespiratory strain (percentage of maximal oxygen consumption, $\%VO_2max$) and muscular strain (percentage of maximal voluntary contraction, %MVC) depend on a person's maximal cardiorespiratory capacity and body weight and maximal muscular strength at a same level of absolute VO_2 and muscle activity (Westgaard 1988, Suurnäkki et al. 1991). Women have about 30% lower VO_2max and 40-60% lower muscular strength than men of the same age (Åstrand & Rodahl 1986, Frontera et al. 1991, Nygård et al. 1991, Ilmarinen 1992). The decline of VO_2max with age is about 1-2% per year after the age of 20-25 years (Åstrand & Rodahl 1986, Ilmarinen et al. 1991a). Muscle strength has also been observed to decrease with age, and the decline varies between different muscle groups (Heikkinen et al. 1984, Viitasalo et al. 1985, Nygård et al. 1991).

Cardiorespiratory strain has been shown to be light or moderate according to the mean heart rate (HRmean) and moderate or hard according to the relative aerobic strain ($\%VO_2max$) in most work tasks in agriculture (Table 2). Women have higher strain in daily work tasks than men due to their lower cardiorespiratory capacity (Ahonen et al. 1990). In forest work the HRmean differed between the work phases, being the highest in bunching (Kukkonen-Harjula & Rauramaa 1984, Hagen et al. 1993). The physical strain and work output of younger subjects is higher than that of older subjects (Hagen et al. 1993).

TABLE 2 Cardiorespiratory (HR, %HRR, %HRmax, VO_2, $\%VO_2max$) strain in different agricultural work tasks

Work task	N[1]	Gender	Age (years) Mean	HR ($beats \cdot min^{-1}$) Mean (SD)	%HRmax Mean	%HRR Mean	VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) Mean (SD)	$\%VO_2max$ Mean (SD)	Reference
Machine milking[2]	3	Male	-	89 (13)	-	21	10 (2)	32	Ahonen et al. (1990)
	15	Female	-	109 (12)	-	38	13 (3)	51	
Manual delivery of ensilage	7	Male	-	111 (9)	-	46	16 (4)	51	Ahonen et al. (1990)
	9	Female	-	121 (19)	-	50	19 (5)	76	
Manual removal of manure	7	Male	-	106 (7)	-	42	15 (5)	47	Ahonen et al. (1990)
	9	Female	-	121 (16)	-	51	16 (5)	66	
Motor-manual tree cutting	15	Male	29	138 (10)	71	-	24 (2)	49 (4)	Hagen et al. (1993)
(felling, limbing, bunching)	16	Male	59	126 (17)	72	-	21 (4)	53 (7)	
	15	Male	34	123 (4)[3]	66[3]	-	-	49 (7)	Kukkonen-Harjula & Rauramaa (1984)
Tree limbing	5	Male	43	103-142[4]	35-68[4]	-	-	40-64[4]	Klen et al. (1991)
Pruning of standing trees	6	Male	22	112 (10)	-	29	-	-	Kirk & Parker (1996)
	17	Male	40	83 (10)	-	21	12 (3)	29 (5)	Costa et al. (1989)

[1]Number of subjects
[2]Tie stall milking
[3]Six subjects
[4]Range

The %MVC of different body parts (shoulders, low back, hips, knees, ankles) has been quantified during the simulation of 20 different milking postures in laboratory situations (Ekholm et al. 1985, Svensson et al. 1985, Arborelius et al. 1986, Nemeth et al. 1990). When the activity of shoulder muscles during milking was quantified, the activity of the shoulder flexors (anterior part of the deltoid) was highest when the floor level difference between the milker and cow was 1.0 m. Men used 24% and women 35% of their MVC (Arborelius et al. 1986). Nemeth et al. (1990) found low muscle activity (<15%MVC) in erector spinae muscles in all milking postures, especially when the milking chair was used. The muscle activity of the knee flexors and extensors was very low in all postures with straight knees or squatting postures but higher (<25%MVC) in bent knee postures with a level difference of 0-0.5 m (Ekholm et al. 1985). The extensors of the ankle (gastrocnemius) showed low activity (<10%MVC) and the flexors (tibialis anterior) no activity in the studied postures (Svensson et al. 1985).

Perceived load can be assessed with different questions, the overall scale for the rating of perceived exertion (RPE) ranging from 6 to 20 (Borg 1970), or with the category-ratio RPE scale developed for different body parts (Borg 1982). Dairy farmers, regardless of age and gender, consider feeding ensilage and milking to be the most demanding tasks with respect to work load (Gustafsson et al. 1994).

Ahonen et al. (1990) inquired about the perceived exertion in different work tasks in dairy farming. The RPE value varied between 11 and 14 (11 = fairly light and 15 = hard) for men and 9 and 15 (9 = very light) for women. Both the male and female farmers rated delivering ensilage and removing manure as somewhat hard to hard (13-15) and female farmers gave milking the same rating. Stål et al. (1996) showed that perceived physical stress is highest in milking during the carrying and lifting of 1 or 2 milking machines, pre-milking, the disconnecting of the milking units, and the attaching of the cluster to the udder. According to Hagen (1993) the bunching phase in forest work is perceived as somewhat hard (RPE 13) or as light (RPE 11) when standard or ergonomic lifting hooks are used, respectively.

2.6 Rehabilitation and environmental measures in agriculture

There are some reports concerning the effects of rehabilitation (Väyrynen & Könönen 1991, Leino et al. 1994, Perkiö-Mäkelä 1996) or environmental measures (Gite 1993, Hagen 1993, Kivikko 1993, Mamansari & Salokhe 1995, Kivikko 1996) carried out in agriculture or forest work. Several authors have recommended preventive programs and ergonomic actions for farmers' work (Thelin 1990, Cordes & Rea 1991, Kaul 1993, Gustafsson et al. 1994, Meyers et al. 1995).

Perkiö-Mäkelä (1996) recently reported group activities (N=126) carried out for female farmers as a part of farmers' occupational health services in 5 municipal health centers. The participants were selected according to the following criteria: (a) female farmer, (b) work on a dairy farm, (c) 25-45 years of age, and (d) musculoskeletal symptoms which had not affected work ability. The group activities, based mainly on physical exercises and training in work techniques, increased musculoskeletal capacity and the frequency of physical exercise sessions, decreased musculoskeletal symptoms but had only a minor effect on the WAI during the 1-year follow-up.

Stål et al. (1996) reported that, with respect to elbow symptoms, there was a significant difference between the female milkers who had received ergonomic instructions on how to reduce muscle strain in their work and those who had not received any training.

Väyrynen & Könönen (1991) reported that training in work techniques during occupationally oriented medical rehabilitation courses changed the work postures of loggers (N=4). The new tree-felling technique that was learned was still in use at the end of the 4-year follow-up period. The rehabilitation course especially decreased the poor work postures of the back and upper limbs and increased the use of the lower limbs.

Klen et al. (1991) compared the Kilk's method (a combination of 6-phase clean cutting and the sweeping) and the traditional sweeping method for debranching trees (N=5). The cardiorespiratory and musculoskeletal load and strain were slightly lower with the Kilk's method.

According to Leino et al. (1994) work-oriented fitness courses for loggers decreased the stress symptoms and work absenteeism more in the experimental group (N=87) than in the control group (N=61) during the 1-year follow-up. The positive change also in perceived physical fitness, health, and work ability was greater in the experimental group than in the control group.

The effects were studied of environmental improvements in dairy barns on farmers' work time, perceived physical stress, work conditions, and work postures. In the first part of the study (Kivikko 1993) 50 farmers who had recently built or renovated their barn were selected as respondents for the telephone interview study. The daily work time was about 30% shorter and the perceived physical work load was lower after the environmental improvements when compared with the earlier situation. In the second part (Kivikko 1996) the work postures of 9 male and 6 female farmers' were analyzed on 9 dairy farms before and after the improvements made in the milking and handling of fodder and manure. The bent and twisted back postures and postures with upper limbs at or over the shoulder level decreased after the environmental measures.

Hagen (1993) analyzed the effects of using longer (0.28 m) lifting hooks than the standard hooks (0.19 m) in the bunching phase in forest work (N=9). A 17-kg log was lifted 15 times per minute in the laboratory. The use of longer hooks resulted in a 12% reduction in VO_2, and the load moments in the hip and L5-S1 were reduced by 14% and 9%, respectively.

Environmental measures (changes in production buildings, machines, and tools) have made farm work possible for farmers with permanent physical impairments. The Purdue project (Field & Tormoehlen 1985, Field & Hancock 1989, Petrea et al. 1996) in the United States and the disabled farmers' program (Elian 1994) in Canada are examples of programs including visitation services, information, newsletters, and workshops aimed to support disabled farmers and their families as they continue work. Field & Hancock (1989) described technical modifications which enable farmers with a spinal cord injury to access and drive tractors and combines, to hitch trailing equipment, and to move around the farm.

2.7 Summary of the literature and the framework of the study

In the future the number of farmers will decrease, farms will become larger, and the level of mechanization will increase. Dairy farming, for which milking constitutes a major part of daily work time, will presumably remain the most important farm operation in Finland.

Work in agriculture is risky, as shown by the prevalence of musculoskeletal disorders and accidents. Musculoskeletal disorders cause the most work disabilities of farmers. The disorders have been shown to be associated with various physical load factors at work.

Farmers' work varies according to the farm operation and the level of mechanization. The results obtained in actual and simulated work tasks show that the postural load is high and the cardiorespiratory strain is light or moderate in most tasks. The hard work is found in forest work, in female farmers' tasks on dairy farms, and in lowly mechanized tasks.

Studies are needed about the effects and effectiveness of different kinds of ergonomic actions, including rehabilitational and environmental measures. The knowledge can be utilized in the activities supporting work ability carried out in farmers' occupational health care and in rehabilitation. A schematic description of the study is presented in Figure 2.

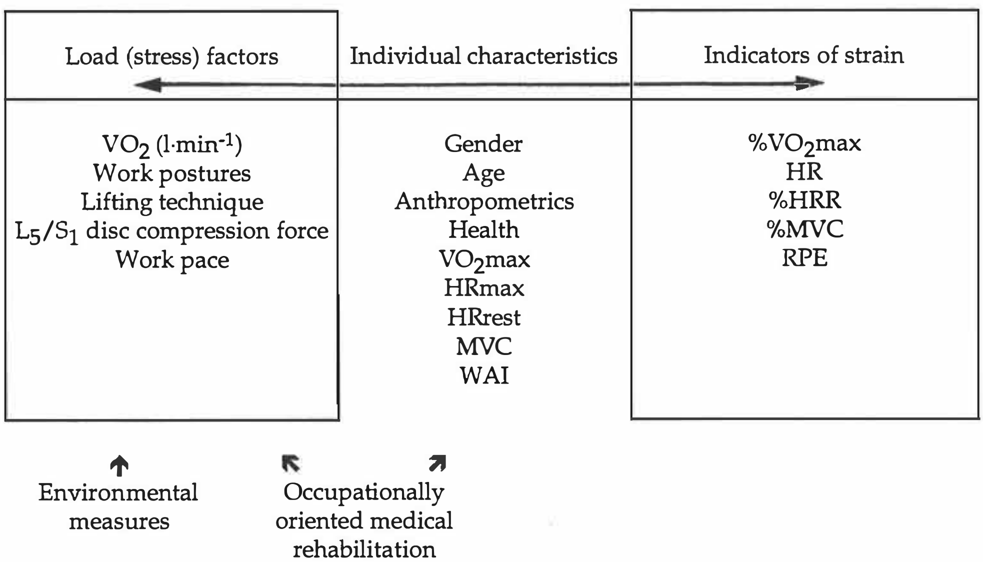

FIGURE 2 The modified stress-strain model as a schematic presentation of the present study

3 AIMS OF THE STUDY

The aim of this study was to assess the effects of occupationally oriented medical rehabilitation and environmental measures on dairy farmers' physical work and ergonomics. The study investigated the physical load and strain of milking in environments representing different degrees of mechanization, it evaluated the effects of occupationally oriented medical rehabilitation courses on farmers' work techniques, and it described the physical strain of farmers with physical disabilities.

The specific questions were:

1. What is the physical load, strain, and work pace of milking in tie stalls and in parlors? (I, II)

2. What are the effects of occupationally oriented medical rehabilitation courses on farmers' work techniques, musculoskeletal pain, and work ability? (III, IV)

3. What daily tasks are farmers with physical disabilities able to perform and what is their physical strain at work? (V)

4 MATERIAL AND METHODS

4.1 Subjects

The subjects in the 5 studies were 52 men and 58 women, all of whom were experienced farmers (Tables 3 and 4). In study I the subjects were 2 male and 3 female farmers from 3 dairy farms where the cows were milked in tie stalls. A milking rail system was installed on these farms. Study II was carried out as a part of a larger project which investigated the work environment, work methods, and physical, chemical and biological exposures on modern Finnish dairy farms (Louhelainen 1996). On these farms a new barn had been built or the old one had been renovated during the last 4 years. The subjects were 3 male and 3 female farmers from 5 dairy farms. The subjects (I, II) had had neck and shoulder pain during the previous year.

The data of studies III and IV were collected as a part of a study investigating the effects of occupationally oriented medical rehabilitation courses on farmers' physical performance and work techniques (Nevala-Puranen 1996). The subjects of study III were 27 female farmers, who experienced low-back or neck and shoulder pain that decreased work ability, whereas 43 male and 52 female farmers with the same types of symptoms were included in study IV. The subjects in study III participated also in study IV. In study III the subjects participated in 4 occupationally oriented medical rehabilitation courses, lasting 3 weeks, organized by the Social Insurance Institution in 1 Finnish rehabilitation center, and in study IV the subjects participated in 10 such courses organized in 3 rehabilitation centers.

In study V the subjects were 4 male farmers who had a physical disability. One subject (L) had had his right thigh amputated 11 years previously, when he had loosened a tuft from a thresher by kicking. He ambulated with a long leg prosthesis without other assistive devices. The right thigh of participant M had been amputated after a car accident 2 years previously. He also used a long leg prosthesis. The entire right lower limb and left ankle of subject N were paralyzed after a traumatic fracture of the first lumbar vertebra. The accident was due to a landslide when excavating an underdrain 4 years previously. He used a long support on the right leg and a short support on the left leg and ambulated with crutches at work and with a wheelchair at home. The left leg of participant O had been amputated below the knee due to a traffic accident 21 years previously. He used a short prosthesis without other assistive mobility devices. The subjects carried out daily work tasks on their farms, and they had a partial pension due to their disability.

Thirty-three percent of the men and 59% of the women were at least 10% overweight according to the body mass index (BMI $\geq$ 27 $kg \cdot m^{-2}$). The physical capacity according to the VO_2max was very poor or poor in 13%, moderate in 44%, and good or very good in 43% of the men. The corresponding proportions in women were 57%, 35%, and 8%, respectively.

The subjects participated in the studies on a voluntary basis, and each subject was provided with adequate and appropriate information either individually (I, II, V) or in group meetings (III, IV) about what their participation would involve. The subjects gave an oral (I, III, IV) or a written (II, V) consent before the beginning of the studies. The study plans were accepted in the research (II, III, IV, V) and ethical (II, V) committees of the Finnish Institute of Occupational Health and in addition in the Social Insurance Institution (III, IV) and in the Farmers' Social Insurance Institution (II, V).

TABLE 3 Physical characteristics of the subjects in case studies I, II and V

Study	N[1]	Subject	Gender	Age (years)	Height (cm)	Weight (kg)	BMI ($kg \cdot m^{-2}$)	VO_2max ($l \cdot min^{-1}$)	VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)
I[2]	5	A	Female	42	166	74	26.9	2.30	31.1
		B	Male	39	188	84	23.8	3.79	45.1
		C	Female	39	163	70	26.3	2.02	28.9
		D	Male	41	177	80	25.5	2.98	37.3
		E	Female	49	168	68	24.1	2.20	32.4
II	6	F	Female	35	163	55	20.7	2.13	38.7
		G	Female	43	155	88	36.6	2.21	25.1
		H	Male	45	171	69	23.6	2.47	35.8
		I	Male	45	178	102	32.2	3.39	33.2
		J	Female	43	157	66	26.8	1.90	28.8
		K	Male	38	185	90	26.3	3.49	39.2
V	4	L	Male	40	171	75	-	2.0	26.7
		M	Male	49	179	95	-	1.4	14.7
		N	Male	34	174	62	20.5	1.3	20.2
		O	Male	37	168	68	-	3.2	47.1

[1]Number of subjects
[2]The values in the first measurements

TABLE 4 Physical characteristics of the subjects in studies III and IV, means (SD) and ranges

Study	N[1]	Gender	Age (years)	Height (cm)	Weight (kg)	BMI ($kg \cdot m^{-2}$)	VO_2max ($l \cdot min^{-1}$)	VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)
III	27	Female	43 (6)	163 (6)	72 (11)	27.3 (3.3)	2.11 (0.4)	30.0 (5.4)
			32-52	156-172	58-94	21.2-33.7	1.49-2.91	18.5-39.7
IV	43	Male	41 (7)	178 (8)	82 (11)	26.4 (3.3)	3.81 (0.7)	44.0 (5.6)
			26-53	165-192	65-110	20.3-34.6	2.58-5.22	34.9-53.0
	52	Female	43 (6)	164 (6)	74 (12)	28.3 (4.2)	2.29 (0.5)	29.6 (4.8)
			26-52	151-172	57-108	21.2-36.1	1.45-3.55	18.5-39.7

[1]Number of subjects

4.2 Farms

In studies I-III the subjects worked on dairy farms. In studies IV-V also other farm operations were represented. In studies I, III, IV and V the barns were tie stalls, but in study II the cows were in loose house systems and milking was done in parlors (Table 5 and 6). The measurements in the case studies (I, II, V) were done during spring time (February-April) and in the intervention studies (III, IV) during February-April and September-November.

TABLE 5 Description of the farms in case studies I, II, and V

Study	Subject	Farm operation	Arable farming land, own and rented (hectares)	Number of animals
I	A,B	Dairy	38	22 dairy cows
	C,D	Dairy	40	24 dairy cows
	E	Dairy	41	29 dairy cows
II	F	Dairy	31	17 dairy cows
	G, H	Dairy	35	20 dairy cows
	I	Dairy	25	22 dairy cows
	J	Dairy	35	13 dairy cows
	K	Dairy	40	20 dairy cows
V	L	Dairy	29	17 dairy cows
	M	Poultry	78	4 000 hens 15 000 broilers
	N	Dairy	19	13 dairy cows
	O	Dairy	64	29 dairy cows

TABLE 6 Description of the farms in studies III and IV

Study	Number of farms	Farm operation	Arable farming land, own and rented, (hectares) Mean (range)	Number of animals Mean (range)
III	27	Dairy	25 (8-50)	15 (6-28) dairy cows
IV	76	Dairy	24 (8-56)	14 (2-30) dairy cows
	8	Meat	29 (14-59)	32 (10-75) bulls
	5	Grain	30 (8-55)	-
	4	Pig	36 (18-70)	255 (80-600) pigs
	2	Vegetable	22 (14-30)	-

4.3 Methods

The methods used in the original papers are summarized in Table 7. In addition, an interview was used to describe the daily work tasks, milking system, work tools and machines, and health of the subjects.

TABLE 7 The variables and their references stated in the original papers

Variable	Study	Reference
Load factors		
* VO_2	I, II	Ballal & MacDonald (1982), Harrison et al. (1982), Louhevaara et al. (1985)
* OWAS	I, II, III, IV	Karhu et al. (1977), Karhu et al. (1981), Mattila et al. (1993)
* Biomechanical load	IV	Chaffin (1988), Chaffin & Andersson (1991)
* Work pace	I	Alakruuvi (1996), Kirk & Parker (1996)
Individual characteristics		
* BMI	I-IV	Fogelholm et al. (1996), Pietinen et al. (1996)
* VO_2max	I-V	Glassford et al. (1965), Oja et al. (1970), Louhevaara et al. (1990), Aminoff et al. (1996)
* MVC	II, V	Westgaard (1988)
* Musculoskeletal pain	IV	Kuorinka et al. (1987), Era et al. (1990)
* WAI	IV	Tuomi et al. (1991a)
Indicators of strain		
* HR	I, II, V	Karvonen et al. (1984), Lèger & Thivierge (1988), Janssen et al. (1994)
* EMG	II, V	Jonsson (1982), Remes et al. (1984), Jonsson (1988), Westgaard (1988), Toivanen et al. (1993)
* RPE	I, II, V	Borg (1970), Borg (1982)

4.3.1 Load factors (I-V)

Oxygen consumption (I, II)

The VO_2 was measured at work with a portable device (Oxylog, P.K. Morgan Ltd, U.K.). The Oxylog measures the volume of inspired air, the partial pressure of oxygen for inspired and expired air, and air temperature (Humphrey & Wolff 1977, Ballal & Macdonald 1982, Harrison et al. 1982, Louhevaara et al. 1985). It weighs 2.6 kg in its leather case (dimensions of 19x8x22 cm). The minute VO_2 was read from the digital display during the work periods of 20 min (I) or 18 min (II). The device was calibrated twice before each measurement, first in the laboratory with a respiratory gas analyzer (Oxycon Mijnhard, The Netherlands) on the day preceding the measurement and second in the barn just before the measurement.

The correlation coefficients between the Oxylog and conventional Douglas bag measurements were 0.99 for standardized walking and 0.91 for lifting work (n=6) in the laboratory (Louhevaara et al. 1985) and 0.99 for 12-min of a continuous exercise test on a treadmill (n=8) (Ballal & MacDonald 1982). In both studies the Oxylog underestimated the VO_2 values when compared with the Douglas bag.

Work postures (I-IV)

The postural load on the musculoskeletal system was analyzed with OWAS (Karhu et al. 1977, Karhu et al. 1981, Mattila et al. 1993). The OWAS observations can be recorded either directly at the worksite or by a video technique. The present OWAS observations were made every 30 s at work (I) or every 10 s from still videotape frames (II, III, IV). The data were stored in a Micronic data collection device (I) or in a microcomputer using the OWAS collection program (OWASCO) (II, III, IV). The results were analyzed with a computer using the Survo and Turvo (I) or OWAS analyzing program (OWASAN) (II, III, IV).

OWAS identifies 4 work postures for the back, 3 for the arms, and 6 plus walking for the legs and estimates the weight of the load handled or the amount of force used. The method classifies single combinations of these factors according to their harmfulness to the musculoskeletal system. The degree of harmfulness of a single posture or posture combination is ranked into 4 action categories that indicate the urgency to change the posture with ergonomic measures. The action categories are 1 = normal posture - no need for corrective measures, 2 = may have a harmful effect - corrective measures needed in the near future, 3 = harmful effect - corrective measures needed as soon as possible, 4 = very harmful effect - corrective measures needed immediately.

The validity of OWAS was shown to be high (Leskinen & Tönnes 1993) when the OWAS observations were compared with the continuous registering of movements. The test-retest reliability of OWAS was r=0.77-0.81 when determined from slides and r=0.60-0.78 when calculated from observations in an actual work situation, when the reliability was stated as the proportion of all observations rated similarly in 2 studies (Salonen & Heinsalmi 1979).

Biomechanical load (IV)

The computerized 2D Static Strength Prediction Program (2D SSPP version 4) was used in analyzing the changes in postural load during lifting (Chaffin 1988, Hagen 1990, Chaffin & Andersson 1991). The initial point of the lift was photographed from still videoframes, and the angles for 5 body links were manually determined from the photographs. The angles for the elbow, shoulder, back, knee and ankle were measured with respect to the horizontal level. The biomechanical data, height and weight of the subject, weight of the load, and the number of lifting arms were stored in a microcomputer. The outcome variable was the predicted static disc compression of the intervertebral disc between the 5th lumbar vertebra and the sacrum (L_5/S_1 disc). The lifting technique (stoop=bent back with straight knees, squat = bent back with flexed knees) was also classified from the photographs (Hagen 1990).

The validity of predicted compressive loads on the lumbar spine has been tested with direct measurements of intradiscal pressure. The correlation coefficient was 0.94 (Schultz et al. 1982). In this study, the reliability of manually determining the body angles from the photographs was tested by analyzing 20 pictures twice with a 1-week interval. Both the inter-rater and test-retest reliabilities were high (r=0.91 and r=0.95, respectively).

Work pace (I)

The work pace was quantified with the use of the whole milking time and the duration of 8 milking phases per cow (Alakruuvi 1996, Kirk & Parker 1996). The time was measured continuously with a stopwatch with a 1-s accuracy.

4.3.2 Individual characteristics (I-V)

Body mass index (I-V)

BMI ($kg \cdot m^{-2}$) was calculated by dividing the weight (kg) by the square of the height (m^2) (I-IV). Overweight was classified as an index value over 25 (III, IV) or over 27 (I, II), obesity being considered values over 30 (Fogelholm et al. 1996, Pietinen et al. 1996). The BMI was not calculated for 3 subjects (study V) because the lack of a leg decreased their weight but not their height.

Maximal cardiorespiratory capacity (I-V)

The maximal oxygen consumption (VO_2max) and the maximal heart rate (HRmax) were assessed in the laboratory using a direct (I-IV partly) or indirect (V) maximal exercise test performed on a bicycle ergometer (I-V partly) or as an arm cranking test (V partly). The indirect submaximal 3-point extrapolation method recommended by the World Health Organization (WHO) (Andersen et al. 1971) was used in most of study IV, and thus the HRmax was the age-specific value (i.e., 220 - age) (ACSM 1995).

In studies I-III the first external work load was 50 W, and it was increased by 25 W (II) or 30 W (I, III, IV) every 2 minutes until exhaustion. In the submaximal test (IV) the first load was 50-100 W, chosen individually, and the load was increased every 4 minutes until the HR was about 85% of the age-specific HRmax. In study V the first work load was 20 W in the bicycle ergometer test and 10 W in the arm-cranking test. The load was increased by 10 W every 2-3 minutes or 5 W every 2 minutes until exhaustion, respectively.

In studies I-IV pulmonary ventilation, VO_2, the production of carbon dioxide and the respiratory exchange ratio were measured every 60 s with a respiratory gas analyzer (Oxycon, Mijnhard, The Netherlands). The criteria for the maximality of the test was the plateau of VO_2 (increase within less than 2 $ml \cdot kg^{-1} \cdot min^{-1}$) and the respiratory quotient $\geq$1.00 (Howley et al. 1995). The electrocardiogram (ECG) was continuously monitored (I, II, V) (Olli Monitor 432, Kone, Finland), or HR was recorded (III-IV) by a cardiotachometer (Sport Tester PE 3000, Polar Electro, Finland). Systolic blood pressure was measured with the conventional auscultatory technique every 2-4 minutes (I-V).

Katch et al. (1982) reported a variability of 5% in the determination of VO_2max for 5 trained subjects, who repeated a maximal exercise test on a treadmill 8-20 times over a 2- to 4-week period. The validity of the 3-point WHO extrapolation method has been tested with the direct VO_2max method using bicycle or treadmill tests, and the correlation coefficient was observed to be high (r=0.81) (Louhevaara et al. 1980). The VO_2max predicted from the submaximal HR and workload is generally within 10% to 20% of the results measured in the laboratory with gas analysis (McArdle et al. 1991). The test-retest reliability of the VO_2max and HRmax was 0.98 and 0.97, respectively, during wheelchair ergometry tests of persons with spinal cord injury (Bhambhani et al. 1991). The standard deviation for HRmax within the same age group is ±10 $beats \cdot min^{-1}$ (McArdle et al. 1991).

Maximal voluntary contraction (II, V)

Before the measurements of local shoulder muscle strain at work the maximal muscle activity of the trapezius muscle was registered bilaterally during MVC. The measurement was done in shoulder elevation with the subject in a sitting position, and fixing belts were used over the shoulders and under the chair (Westgaard 1988). The subject was allowed 2 practice trials, and thereafter 2 or 3 trials were performed. The highest EMG value (in microvolts) attained was accepted as the result.

Musculoskeletal pain (IV)

The amount of musculoskeletal pain (IV) in 9 body parts (neck, shoulders, elbows, wrists or hands, upper back, low back, hips, knees and ankles or feet) was rated on 100-mm visual analogue scales (VAS) (range 0-100; end points: no pain-unbearable pain) of the pain line questionnaire. The pain index was the mean of the 9 estimations.

The pain questionnaire has been developed (Era et al. 1990) on the basis of the Nordic questionnaire (Kuorinka et al. 1987), the validity of which has been tested with the interviews (Kemmlert & Kilbom 1988). In the present study, the test-retest reliability of the pain lines used was assessed for 20 office-working women (mean age 40 years, height 164 cm, weight 67 kg) who were selected from 1 workplace. The subjects filled out the questionnaire twice with a 1-week interval, and the correlation coefficient between 2 measurements was 0.79.

Work ability (IV)

The WAI was used to assess subjective work ability (Eskelinen et al. 1991, Tuomi et al. 1991b). The questionnaire-based method covered 7 items, each of which was evaluated with 1 or more questions. The items of the WAI were current work ability compared with the lifetime best, work ability in relation to the physical and mental demands of the job, number of current physician-diagnosed diseases, estimated work impairment due to the diseases, sick leave during the past 12 months, own prognosis of work ability 2 years from now, and mental resources. The agreement of the WAI with clinical examinations is good (Eskelinen et al. 1991), and the WAI also reliably predicts work disabilities among aging municipal employees in different occupational groups (Tuomi et al. 1991c).

4.3.3 Indicators of strain (I, II, V)

Heart rate (I, II, V)

HR was recorded at work in 15-s (II, V) or 60-s (I) intervals by an ambulatory telemetric cardiotachometer [Sport Tester PE 3000 (I) or Polar Sport Tester (II, V) Polar Electro Oy, Finland]. The percentage of the HR range (%HRR) was calculated with the equation: (HRmean - HRrest)/(HRmax - HRrest) x 100 (Karvonen et al. 1957). The resting heart rate (HRrest) was the lowest HR value recorded in a sitting position before the exercise test, the HRmean was the mean value measured in a work situation, and the HRmax was the highest value recorded in the exercise test in the laboratory.

The validity of the Sport Tester has been shown to be high (Lèger & Thiviegre 1988), and the HR values differ by 5 beats·min^{-1} at most from HR recorded simultaneously from ECG at submaximal work loads (Karvonen et al. 1984). The day-to-day variation in HR is about ±5 beats·min^{-1} at the same exercise load (McArdle et al. 1991). High correlations (r=0.95 and 0.71), both at lower (65-75 %HRmax) and higher (85-95 %HRmax) work loads are reported (Lèger & Thiviegre 1988). The reliability of steady state HR in submaximal cycling has been reported to be high (r=0.86-0.89) (Becque et al. 1993). In addition the Sport Tester PE 3000 has reliably measured HR responses (e.g., to nonsteady-state tasks) in men with spinal cord injuries (Janssen et al. 1994).

Muscle activity (II, V)

Amplitude distributions of full-wave rectified and averaged surface EMG signals were used to quantify the shoulder muscle load and strain in different work tasks. The EMG of the trapezius muscle (pars descendens) was measured (II, V) with a programmable EMG microcomputer (ME3000P, Mega Electronics Ltd, Finland) with a video option (Remes et al. 1984, Toivanen et al. 1993). Before the recordings the skin was cleaned with alcohol and rubbed with rough plastic. The battery-operated device (weight 400 g) was carried in a pocket during work. The muscle activity was recorded using the averaged mode, a 0.1-s interval and the bipolar setting of disposable surface electrodes. The work was also video-recorded with a Panasonic S-VHS-C video camera.

The mean (SD) muscle activity in different work tasks was analyzed by the attached software. The results were compared to the limit values recommended by Jonsson (1978) for work with a duration of 1 hour or more: the static load level should not exceed 2%MVC and must not exceed 5%MVC. The mean (or median) load level should not exceed 10%MVC and must not exceed 14%MVC; and the peak loads should not exceed 50%MVC and must not exceed 70%MVC.

The reproducibility of the EMG measurements with the surface electrodes was 0.69 in maximal and 0.57-0.79 in submaximal (20-80%) voluntary contractions of the biceps brachii muscle in 8 subjects (Komi & Buskirk 1970). Yang & Winter (1983) showed a correlation coefficient of 0.78-0.89 within days and 0.88-0.95 between days in submaximal contractions of triceps muscle (n=9). The corresponding ranges in maximal contractions were 0.52-0.61 and 0.68-0.81, respectively. The variation coefficient ranged from 8% to 10% in the within-day measurements and from 12% to 16% between different days.

Perceived exertion (I, II, V)

RPE was recorded every 3 minutes (V) or 5 minutes (I, II) according to the scale, ranging from 6 to 20 (Borg 1970, Borg 1982). The odd numbers on the scale were described as follows: 7 very, very light; 9 very light; 11 light; 13 fairly hard; 15 hard; 17 very hard; 19 very, very hard.

Edwards et al. (1972) reported correlation coefficients of 0.88, 0.97, 0.94 and 0.77 between the RPE and HR, VO_2, ventilation, and blood lactate concentration, respectively, during continuous bicycle exercise. The reliability for the maximal RPE between 2 tests has been shown to be high (r=0.92) during wheelchair ergometry tests of persons with spinal cord injury (Bhambhani et al. 1991).

The correlations between RPE and physiological responses in work situations have been reported to be low. Louhevaara (1993) reported the correlations of 0.41, 0.37, 0.32 and 0.48 between the RPE and VO_2, HR, systolic blood pressure and work output ($parcels \cdot min^{-1}$), respectively, during the manual sorting of postal parcels. Hjelm et al. (1995) showed a correlation coefficient of 0.43 between RPE and HR and 0.37 between RPE and %HRR when the RPE was recorded after the workday from men representing different occupations. In the present study the correlation between RPE and HR for the disabled subjects (V) was assessed in the maximal exercise tests and during the work. The correlation was high (r=0.91) in the exercise tests but low (r=0.48) during the field measurements.

4.3.4 Occupationally oriented medical rehabilitation (III, IV)

The occupationally oriented medical rehabilitation courses, a Finnish model of rehabilitation, were developed, organized and paid for by the Social Insurance Institution in Finland for the working age population. The 10 studied courses lasted for 3 weeks and were organized in 3 rehabilitation centers; the courses included a 6-month follow-up in 1 rehabilitation center (III, partly IV) and a 1-year follow-up in all the centers (IV). All the subjects were paid a daily rehabilitation grant. The goals of the courses were to increase the subjects' physical and psychological capacities and to teach them work techniques that optimize the musculoskeletal load in daily work tasks (Väyrynen & Könönen 1991, Leino et al. 1994, Nevala-Puranen 1996).

The selection criteria of the Social Insurance Institution included the following prerequisites: (a) if possible, age at most 45 years, (b) full-time farmer at least 3 years and intention to continue, (c) musculoskeletal symptoms causing sick leave for a maximum of 60 days during the last 2 years, (d) no other deseases that prevent rehabilitation, (e) motivation to work, and (f) voluntary participation in the course.

The courses included mainly training of ergonomic work and lifting techniques in daily tasks (milking, handling ensilage, cow brushing, and floor cleaning), physical exercise sessions (endurance, muscular strength, stretching, relaxation) and learning of the structure and physiological strain responses of the musculoskeletal system. In this study, no modifications were made to the contents of the rehabilitation courses. The training of work techniques (about 25 hours per course) first took place in a simulated situation in the classroom and then in the actual work environment (in tie stalls). The ergonomic work techniques were taught in groups by a physiotherapist and a teacher of agricultural work. In the beginning of the courses the individual work techniques were video-recorded, and the recordings were used when the participants were given feedback of their work techniques and motivated to change them. A special objective was to learn to transfer the load from the arms and back to the legs. The use of a milking chair, knee protectors, and tools with long handles was also taught.

4.3.5 Environmental measures (I, II, V)

The subjects had carried out the environmental measures themselves. This study assessed farmers' physical load and strain before and after (I) or after (II, V) these measures. The milking rail system (I) made it possible for the subjects to transfer the milking equipment (i.e., milking units, cleaning equipment, and cup of milk tips) by pushing it in the rail (hanging from the roof) from the milkroom to the barn. Before acquiring the rail system, 2 subjects (C, D) carried their milking equipment, and the other subjects (A, B, E) transferred the equipment with a milking cart from the milkroom to the cows.

The farmers in study II had built a new barn or renovated the old one during the previous 4 years. The new barns were warm loose housing buildings and milking was done in milking parlors.

In study V each of the 4 subjects had taken environmental measures to improve their work ability because of their physical disability (Table 8).

TABLE 8 Environmental measures carried out by the subjects with physical disabilities (V)

Subject	Diagnosis	Farm operation	Environmental measures
L	Amputation of right leg above the knee	Dairy	- vacuum flour mill - quick attachment devices in the tractor - great sack system - telephone in the tractor and in the car - automatic gears in the car
M	Amputation of right leg above the knee	Poultry	- gas pedal on the left side in the tractor - special hydraulics - automatic gears in the car
N	Paraplegia	Dairy	- manually operated brake on the left and gas on the right in the tractor - turning chair with heating and adjustable supports in the tractor - automatic gears in the car
O	Amputation of left leg below the knee	Dairy	- milking chair - milking waistcoat for transferring the milking equipment - removal of differences in floor levels in the barn - automatic deliverer of flour

4.3.6 Statistical methods (I-V)

The statistical analyses were done by the SAS Statistical Package (SAS 1985). Means (III-V), medians (IV), lower and upper quartiles (IV), standard deviations (III, IV), ranges (I, II, V), and distributions (I, II, III, IV) were used to describe the data. The statistical significance of the differences between the means was analyzed by Student's *t*-test for paired observations (IV). In the OWAS analysis (IV), about 70 observations were recorded in each measurement of the subjects, and the percentage distribution (cumulating to 100%) of each body part was calculated according these values. The multivariate variance analysis was used to test the changes in repeated measurements of work postures. The level of statistical significance was defined as $p < 0.05$.

5 RESULTS

5.1 Physical load, strain and work pace in milking (I, II)

5.1.1 Cardiorespiratory load and strain (I, II)

The mean VO_2 during milking varied between 0.6 and 1.0 $l{\cdot}min^{-1}$ in the tie stalls and between 0.3 and 1.1 $l{\cdot}min^{-1}$ in the milking parlors (Table 9). The $\%VO_2max$ of the work in the tie stalls and parlors ranged from 15% to 49% and from 8% to 32%, respectively. The HRmean ranged from 65 to 116 $beats{\cdot}min^{-1}$ during milking in the tie stalls and from 90 to 101 $beats{\cdot}min^{-1}$ in the parlors. The highest %HRR was measured for subject C (42 %HRR) during milking with the rail system in a tie stall. Eight subjects considered the milking work to be very light or light (RPE 9-11), and 3 subjects rated the work as moderately heavy (RPE 13).

5.1.2 Musculoskeletal load and strain (I, II)

The subjects worked with their back straight (OWAS: Back 1) 28-55% of the milking time in the tie stalls without a rail system and 31-68% of the milking time in the tie stalls with a rail system (Table 10). The corresponding range for parlor milking was 76-94% (Table 10). The proportion of postures with the back bent forward and twisted simultaneously (OWAS: Back 4) ranged from 9% to 47% in tie stall milking without a rail system and from 0% to 15% with a rail system (Table 10). The corresponding range for parlor milking was 0-3% (Table 11). In the parlors no posture combinations were used that required immediate corrective measures (OWAS action category 4), while in the tie stalls the proportion of this category ranged from 0% to 36% without a rail system and from 0% to 11% with a rail system

TABLE 9 VO_2, $\%VO_2max$, HR, %HRR, and RPE during milking in tie stalls without and with the rail system (I) and in parlors (II). The mean values are presented.

Working environment Subject	Gender	Duration of measurement (min)	VO_2 ($l \cdot min^{-1}$)	$\%VO_2max$	HRmean ($beats \cdot min^{-1}$)	%HRR[1]	RPE (6-20)
Tie stall, without rail system							
A	Female	62	0.6	26	107	36	12
B	Male	70	0.6	15	68	11	10
C	Female	57	0.8	43	112	40	13
D	Male	69	0.9	31	85	25	11
E	Female	64	1.0	46	108	34	10
Tie stall, with rail system							
A	Female	60	0.6	29	93	21	11
B	Male	50	0.6	15	65	8	9
C	Female	56	0.9	49	116	42	13
D	Male	68	0.8	26	74	9	11
E	Female	63	0.9	47	104	33	10
Parlor							
F	Female	82	0.4	18	101	26	10
G	Female	80	0.4	18	90	25	13
H	Male	85	0.6	24	96	30	9
I	Male	99	1.1	32	90	16	13
J	Female	59	0.5	27	100	30	11
K	Male	96	0.3	8	91	15	10

[1](HRmean - HRrest)/(HRmax - HRrest)] x 100 (Karvonen et al. 1957)

TABLE 10 Proportion of work postures (% of all observations) for 5 subjects when milking in tie stalls without (WO) or with (W) a rail system (I)

Description	Subject A		Subject B		Subject C		Subject D		Subject E	
	WO	W	WO	W	WO	W	WO	W	WO	W
Number of observations	120	128	126	124	123	132	121	120	125	136
Back										
1. Straight	28	38	49	31	29	49	40	68	55	64
2. Bent forward, backward	50	43	24	58	20	36	14	11	35	33
3. Twisted or bent sideways	1	4	1	3	4	2	6	6	1	3
4. Bent and twisted	21	15	26	8	47	13	40	15	9	0
Arms										
1. Both arms below shoulder level	85	99	83	100	87	87	75	85	82	86
2. One arm at or above shoulder level	13	1	15	0	12	12	20	13	10	14
3. Both arms at or above shoulder level	2	0	2	0	1	1	5	2	8	0
Legs										
1. Sitting	80	67	50	66	1	0	0	0	0	0
2. Standing with both legs straight	6	20	16	19	30	45	26	56	28	39
3. Standing with one leg straight	2	0	17	0	1	0	8	6	6	0
4. Standing or squatting with both knees bent	1	0	2	0	46	33	44	8	38	30
5. Standing or squatting with one knee bent	0	0	0	0	6	0	2	0	0	0
6. Kneeling on one or both knees	0	0	0	0	0	1	0	0	0	0
7. Walking or moving	11	13	15	15	16	21	20	30	28	31
Load / use of force										
1. Less than 10 kg (100 N)	100	99	100	100	99	100	94	100	98	100
2. 10-20 kg (100-200 N)	0	1	0	0	1	0	6	0	0	0
3. Over 20 kg (200 N)	0	0	0	0	0	0	0	0	2	0
Action categories										
1. No corrective measures needed	29	42	50	34	31	50	45	74	51	62
2. Corrective measures needed in the near future	66	58	48	66	18	16	9	18	16	13
3. Corrective measures needed as soon as possible	4	0	2	0	15	23	11	3	25	25
4. Corrective measures needed immediately	1	0	0	0	36	11	35	5	8	0

TABLE 11 Proportion of work postures (% of all observations) for 6 subjects when milking in the parlors (II)

Description	Subject F	G	H	I	J	K
Number of observations	460	360	112	360	172	360
Back						
1. Straight	85	76	94	87	81	85
2. Bent forward, backward	11	12	1	11	18	11
3. Twisted or bent sideways	2	9	5	1	1	3
4. Bent and twisted	2	3	0	1	0	1
Arms						
1. Both arms below shoulder level	72	59	82	94	76	75
2. One arm at or above shoulder level	23	17	16	5	20	17
3. Both arms at or above shoulder level	5	24	2	1	4	8
Legs						
1. Sitting	5	0	0	29	0	22
2. Standing with both legs straight	79	75	90	46	69	50
3. Standing with one leg straight	2	2	0	1	1	0
4. Standing or squatting with both knees bent	0	5	1	1	1	1
5. Standing or squatting with one knee bent	0	0	0	0	1	0
6. Kneeling on one or both knees	0	0	0	0	0	0
7. Walking or moving	14	18	9	23	28	27
Load / use of force						
1. Less than 10 kg (100 N)	100	100	100	100	100	100
2. 10-20 kg (100-200 N)	0	0	0	0	0	0
3. Over 20 kg (200 N)	0	0	0	0	0	0
Action categories						
1. No corrective measures needed	93	85	98	88	81	84
2. Corrective measures needed in the near future	7	10	2	11	17	11
3. Corrective measures needed as soon as possible	0	5	0	1	2	4
4. Corrective measures needed immediately	0	0	0	0	0	0

The %MVC was 2-8% on the right trapezius muscle and 2-6% on the left trapezius muscle (II). Subject G had the highest EMG activity in the right trapezius muscle and her work load in the shoulder area was also the most asymmetrical (Figure 3). The highest EMG activities in the trapezius muscle were quantified for each subject when they attached the milking units.

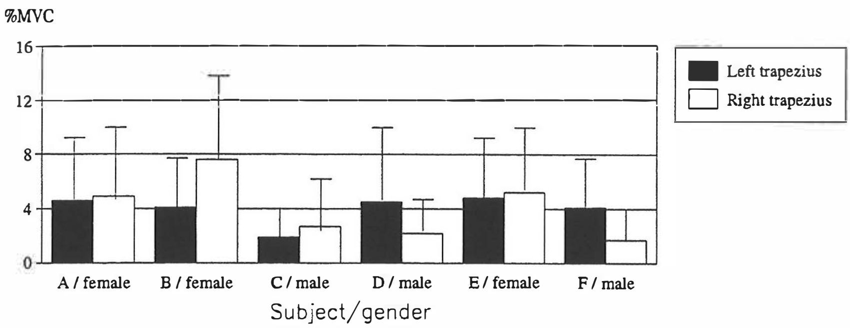

FIGURE 3 Mean (SD) relative local muscular strain (%MVC) of the left and right trapezius muscles of 6 subjects during milking in a parlor (II)

5.1.3 Work pace (I)

The total milking time (including rest, disturbances, and other work) in tie stalls ranged from 42 to 56 minutes without a rail system and from 38 to 56 minutes with a rail system. The milking time per cow varied between 1.7 and 5.6 minutes without a rail system and between 1.6 and 4.0 minutes with a rail system (Table 12).

TABLE 12 Milking time (including rest, disturbances and other work) per cow for each subject when milking in tie stalls without or with a rail system

Subject	Without rail system			With rail system		
	Milking time per cow (min)	Number of cows	Whole milking time (min)	Milking time per cow (min)	Number of cows	Whole milking time (min)
A	3.9	12	47	4.0	12	48
B	5.6	10	56	3.8	10	38
C	3.5	12	42	2.2[1]	20	44
D	4.5	12	54	2.8[1]	20	56
E[2]	1.7	29	49	1.6	32	51

[1]Subject C cleaned the udder and took the milk tips of each cow and subject D attached the milking units to the cows
[2]Automatic stoppage of milking and removal of milking units

5.2 Effects of rehabilitation courses on farmers' work techniques, musculoskeletal pain and work ability (III, IV)

5.2.1 Work techniques (III, IV)

The number of poor work postures for the back, arms and legs was smaller after the ergonomic training during occupationally oriented rehabilitation and in the 1-year follow-up than before the rehabilitation took place (Table 13). Before the rehabilitation the men and women worked with a simultaneously bent and twisted back in 22% and 34% of all the observations, respectively. After 1 year the proportion was 9% and 3%, respectively. The proportion of postures with one or both arms at or above shoulder level decreased from 23% to 10% for the men and from 44% to 15% for the women. Working in sitting or kneeling postures increased, because 11 men and 19 women started to use either a milking chair or knee protectors during milking.

The changes in 4 OWAS work posture combinations were also quantified for 3 common work tasks (milking, handling of ensilage, cleaning of cows or floors) during the 6-month follow-up of the women (III). The work-posture combinations belonging to action category 1 (no need for corrective measures) increased and those in action category 4 (corrective measures needed immediately) decreased in each studied work task (Figure 4). The posture combinations of action category 3 (corrective measures needed as soon as possible) decreased in milking but increased in the handling of ensilage and the cleaning of cows or floors.

TABLE 13 Mean proportion of work postures (% of all observations) used before and after the 3-week rehabilitation courses and in the 1-year follow-up and the statistical significance of the change (IV)

Description	Men (N^1=19) Before (1)	After (2)	1-year (3)	p^2 (1-3)	Women (N^1=27) Before (1)	After (2)	1-year (3)	p^2 (1-3)
Number of observations	1368	1366	1365		1944	1945	1947	
Back				<0.001				<0.001
1. Straight	32	40	39		22	48	50	
2. Bent forward, backward	40	50	49		31	46	46	
3. Twisted or bent sideways	6	3	3		13	2	1	
4. Bent and twisted	22	7	9		34	4	3	
Arms				<0.001				<0.001
1. Both arms below shoulder level	77	89	90		56	76	85	
2. One arm at or above shoulder level	21	10	9		31	13	7	
3. Both arms at or above shoulder level	2	1	1		13	11	8	
Legs				<0.01				<0.001
1. Sitting	1	9	6		3	7	10	
2. Standing with both legs straight	56	44	50		53	41	41	
3. Standing with one leg straight	7	3	1		4	2	1	
4. Standing or squatting with both knees bent	18	17	17		27	23	26	
5. Standing or squatting with one knee bent	1	0	0		1	0	0	
6. Kneeling on one or both knees	0	6	7		1	11	6	
7. Walking or moving	17	21	19		11	16	16	
Load / use of force				>0.05				>0.05
1. Less than 10 kg (100 N)	100	100	100		100	100	100	
2. 10-20 kg (100-200 N)	0	0	0		0	0	0	
3. Over 20 kg (200 N)	0	0	0		0	0	0	
Action categories				>0.05				<0.01
1. No corrective measures needed	36	41	41		33	46	47	
2. Corrective measures needed in the near future	46	41	41		36	26	28	
3. Corrective measures needed as soon as possible	14	15	16		17	23	23	
4. Corrective measures needed immediately	4	3	2		14	5	3	

The multivariate variance analysis
[1]Number of subjects
[2]The statistical significance refers to the percentage distribution of each variable

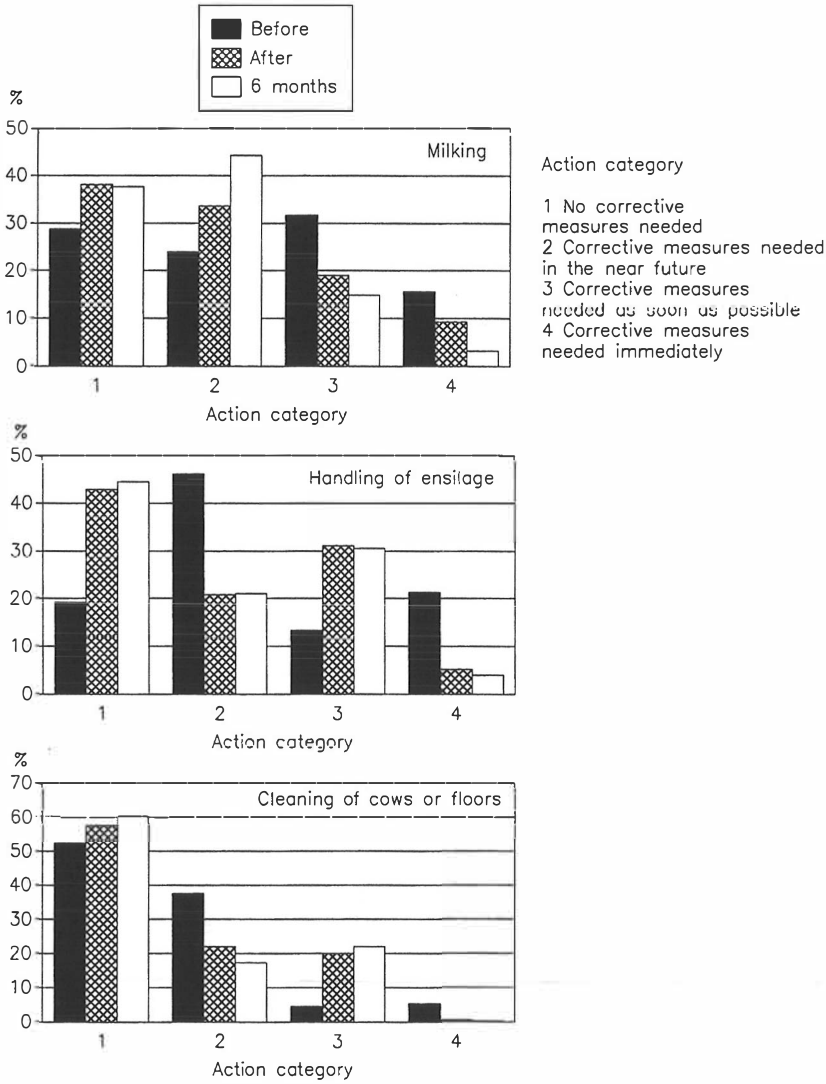

FIGURE 4 Mean proportion of the OWAS work posture combinations (% of all observations) categorized into 4 OWAS action categories for different work tasks before and after the rehabilitation courses and after 6 months of follow-up of the women (N=27) (III)

In the beginning of the rehabilitation courses 89% of the men lifted a sack (weight 30 kg) from the floor from the squat posture (i.e., bent back with flexed knees) and 11% from the stoop (bent back with straight knees) posture (IV). The corresponding proportions of the women lifting a sack of 20 kg were 78% and 22%, respectively. In the 1-year follow-up 88% of the men and all the women used a squat lifting technique. When lifting the sack from a level of 0.45 m, 43% of the men and 50% of the women lifted from the stoop posture in the beginning of the rehabilitation, but after 1 year 94% of the subjects used the squat lifting technique. The changes in the lifting technique significantly increased the biomechanical load of the back in the men (Table 14) (IV).

TABLE 14 Static back compression force (N) during sack lifting (men 30 kg, women 20 kg) from the floor level and 0.45 m from the floor before and after the rehabilitation courses and after 1 year of follow-up and the statistical significance of the change (IV). The mean (SD) values are presented.

	Men					Women				
Level	N[1]	Before (1)	After (2)	1 year (3)	*p* (1-3)	N[1]	Before (1)	After (2)	1 year (3)	*p* (1-3)
floor	10	4452 (654)	4630 (591)	4813 (770)	<0.05	15	3202 (440)	3042 (445)	3047 (480)	>0.05
0.45 m	7	3480 (970)	3580 (987)	4245 (1398)	<0.05	5	2841 (359)	2752 (430)	2825 (599)	>0.05

Student's *t*-test for paired observations
[1]Number of subjects

5.2.2 Musculoskeletal pain (IV)

Using VAS, the amount of musculoskeletal pain in the neck, low back and hips was lower for the women ($p < 0.001$) and that of the low back was lower for the men ($p < 0.01$) after the 1-year follow-up than before the rehabilitation (Table 15).

TABLE 15 VAS (mm) in different body parts of the men and women before the rehabilitation and after the 1-year follow-up and the statistical significance (IV). The median and lower and upper quartiles are given.

	Men (n=42)			Women (n=48)		
	Before rehabilitation	1 year after rehabilitation	*p*	Before rehabilitation	1 year after rehabilitation	*p*
Neck	24 (0-45)	10 (2-31)	<0.05	38 (12-54)	13 (1-41)	<0.001
Shoulders	27 (6-45)	13 (2-36)	>0.05	47 (23-65)	24 (1-56)	<0.01
Upper back	3 (1-29)	2 (0-20)	>0.05	28 (2-49)	10 (0-30)	<0.01
Lower back	52 (19-63)	25 (6-49)	<0.01	52 (24-75)	18 (4-48)	<0.001
Elbows	2 (0-11)	2 (0-25)	>0.05	10 (1-43)	4 (0-29)	>0.05
Wrists, hands	2 (0-4)	1 (0-6)	>0.05	6 (0-49)	3 (0-30)	>0.05
Hips	5 (2-28)	5 (0-33)	>0.05	43 (4-63)	9 (1-41)	<0.001
Knees	10 (2-44)	4 (0-43)	>0.05	12 (1-59)	10 (0-36)	>0.05
Ankles, feet	3 (1-14)	3 (0-8)	>0.05	20 (1-45)	4 (0-39)	<0.05

Student's *t*-test for paired observations

5.2.3 Work ability index (IV)

The WAI was higher for both the men ($p < 0.05$) and the women ($p < 0.01$) after the 1-year follow-up than before the rehabilitation (Table 16).

TABLE 16 WAI[1] of the men and women before the rehabilitation and after 1 year of follow-up and the statistical significance (IV). The mean (SD) values are given.

Gender	N	Before rehabilitation	1 year after rehabilitation	*p*
Men	41	33.5 (4.8)	35.1 (5.7)	<0.05
Women	47	33.5 (5.4)	36.5 (5.8)	<0.01

Student's *t*-test for paired observations
[1]Categories of the WAI: 7-27 = poor, 28-36 = moderate, 37-43 = good, and 44-49 = excellent.

5.3 Physical strain of farmers with physical disabilities (V)

Work tasks

There were several farm-related tasks which the subjects with disabilities (L, M, N, and O) indicated they were unable to perform because of their disability or because they needed regular assistance from neighbors or family members to perform the tasks (Table 17). The transferring of animals was impossible for all 4 of the studied subjects. Three of the subjects were unable to perform difficult operating and repairing tasks and the lifting of heavy materials. All the subjects were able to do field work with a tractor. Milking, forest work, and difficult operating and repairing tasks were possible only for subject O.

TABLE 17 Agricultural work tasks the subjects with disabilities were unable to perform (V)

Subject	Diagnosis (duration, years)	Work tasks unable to perform[1]
L	Amputation of right leg above the knee, (11)	Milking Transferring animals Difficult operating and repairing tasks Forest work Lifting of heavy materials
M	Amputation of right leg above the knee, (2)	Reception of fryers Chicken sampling Use of cleaning machine Difficult operating and repairing tasks Emptying and cleaning of henhouse Attachment of work machines to tractor Forest work Lifting of heavy materials
N	Paraplegia, (4)	Milking Delivery of ensilage and hay Transferring of animals Operating and repairing tasks Attachment of trailer to tractor Forest work Lifting of heavy materials
O	Amputation of left leg below the knee, (21)	Transferring of animals

[1]Farm operation was dairy except for subject M (poultry)

Physical strain

The HRmean ranged from 88 to 103 beats·min^{-1} and the mean %HRR ranged from 17% to 31% for the studied work tasks (Table 18). According to the VO_2, physically heavy or very heavy work (WHO 1978) varied between 0% and 31% of the studied work time. The highest HR values were recorded while the subject handled and delivered ensilage (subject L and O), climbed a ladder or cleaned the manure disposal system (subject M), and pushed a cart of flour (subject N).

For the left and right trapezius muscles the %MVC ranges were 2-7% and 3-7% (subject L), 4-9% and 3-9% (subject M), 2-5% and 0.4-8% (subject N), and 5-9% and 4-6% (subject O), respectively.

The mean RPE of the subjects varied from very, very light (7) to hard (14). The subjects perceived delivering of ensilage (subject L and O), walking and inspecting the farm or packing of eggs (subject M), and delivering of flour (subject N) as the most strenuous work tasks.

TABLE 18 Studied work tasks, length of the measurement, and HRmax, HRmean, %HRR and RPE of each subject during 1 morning work period. The mean values are presented.

Subject, age (years)	Studied work tasks	Length of measurement (min)	HRmax (beats·min^{-1})	HRmean (beats·min^{-1})	%HRR[1]	RPE (6-20)
L (40)	Handling ensilage Handling hay Cleaning floors Bedding	134	188	101	27	12
M (49)	Sorting eggs Inspecting Cleaning floors with a machine Climbing to the drier	134	169	103	31	14
N (34)	Delivering flour Standing and inspecting Washing milking machine	129	187	97	19	7
O (37)	Delivering ensilage Milking Releasing ensilage with tractor	156	187	88	17	12

[1](HRmean - HRrest)/(HRmax - HRrest)] x 100 (Karvonen et al. 1957)

6 DISCUSSION AND CONCLUSIONS

6.1 Methodological considerations

6.1.1 Characteristics of the subjects

This study contained 2 cross-sectional investigations (II, V) and 3 intervention programs (I, III, IV). Three of the studies were case studies (I, II, V). The number of subjects in the case studies was small (4-6 subjects), and therefore the data should be considered descriptive and cannot be generalized because statistical analyses were not possible.

The age of the subjects varied between 26 and 53 years; one-third (35%) of the subjects were over 45 years of age (ageing workers). Theoretically, all the subjects still had at least 10 work years as farmers left ("legal" retirement age is 65 years). Most of the subjects (82%) came from dairy farms, which is the most typical type of farm in Finland. In studies I-IV 33% of the men and 59% of the women were overweight (BMI $\geq$ 27 $kg{\cdot}m^{-2}$); the proportion of men was lower and that of women higher than the proportions of Finnish men (43%) or women (34%) in general (Fogelholm et al. 1996).

In studies III and IV the subjects were selected for occupationally oriented medical rehabilitation according to the selection criteria used by the Social Insurance Institution. The limitation of the intervention studies (III, IV) was the lack of a control group.

The results of study V can hardly be extrapolated to all farmers with physical disabilities. It was difficult to find farmers who use a cain, crutches, prosthesis, or wheelchair at work. The registers of farmers include no information about assistive mobility devices; the same deficiency also concerns persons with disabilities in other occupations (Petäkoski-Hult 1995). It is evident that the 4 disabled farmers in study V represent the most active and most motivated group of disabled farmers because, most disabled persons, especially those using assistive mobility devices, are retired. The mean age (42 years) of the 3 subjects with a lower limb amputation corresponds to the mean age of all persons with traumatic lower limb amputation in Finland (Alaranta et al. 1995). It is obvious, that farmer's physical work requires a well-fitting prosthesis, which is not self-evident, and the ability to walk on slopes and uneven ground (Ward & Meyers 1995).

All the subjects were well motivated. In studies I-II the subjects organized their work to be able to travel to the laboratory for the maximal exercise tests (at most 100 km). They were also willing to take the researchers to their farm to perform the measurements. In studies III and IV the farmers' own motivation towards rehabilitation and the continuation of work were among the selection criteria of the Social Insurance Institution.

6.1.2 Evaluation of methods

In this study the physical work load and strain was studied during samples of farmers' work. The results from the short period during 1 day cannot however, be extrapolated to evaluate the average physical demands and strain consequences of the work (Malchaire et al. 1984). In addition, the presence of researchers may have induced the workers to modify their work pace and techniques, although they were requested to work in a habitual manner.

The methods used in this study complemented each other by describing different aspects of physical work load and strain (i.e., cardiorespiratory, musculoskeletal, perceived). The validity and reliability of most of the methods were known to be good when used by trained researchers. The HR, muscle activity and RPE measurements were used to assess the physical load and strain of the physically disabled subjects in habitual work situations (V). No earlier reports were found concerning the physical strain of workers with disabilities in actual work situations.

Upper limits of physical strain

Work load and strain, determined according to the VO_2, $\%VO_2max$ and HR measurements, were compared with the WHO classification of physical work load and strain (WHO 1978). Several other gender and age-specific classifications of physical work load and strain exist (Åstrand 1987). Recommendations for the upper general tolerance limit of cardiorespiratory strain at work varies between 30% (Petrofsky & Lind 1978) and 50% (Åstrand 1960) of $\%VO_2max$. According to the studies of Jørgensen (1985), Ilmarinen (1992), and Hjelm et al. (1995) the 30%HRR has been kept as the upper limit for an 8-h workday for physical work. Evans et al. (1980), Levine et al. (1982), and Åstrand & Rodahl (1986) showed that, at or below $40\%VO_2max$, a person can work continuously for an 8-h period without becoming fatigued. Grandjean (1988) suggested an average HR increase of 35 and 30 $beats{\cdot}min^{-1}$ above the resting level for men and women, respectively, as an upper limit for continuous performance during an 8-h workday.

The present results of the muscle activity were compared with the recommendations of Jonsson (1978, 1982) concerning a permissible level of static, dynamic, and peak muscle loads of MVC. The scientific basis for these suggestions is not well established.

Measurements of load factors

The reliability of the Oxylog device has been shown to be high in the laboratory (Harrison et al. 1982, Louhevaara et al. 1985), but no studies have been done under field conditions, where the device is mostly used. There are some factors which may have affected the results in these studies (I, II). In the calculations of VO_2 the relative humidity of inspired air is supposed to be 50% (Harrison et al. 1982). In Finnish barns it has been shown to be 65-89% in autumn and 59-96% in winter (Linnainmaa et al. 1993). The subjects carried the instrument on their back, and therefore the small digits on the display were difficult for the observer to read during work tasks requiring quick moving between animals. An additional display with larger digits would have been preferable. In addition, carrying the measuring device and wearing the mask can in themselves affect HR and pulmonary ventilation. The measuring range of the instrument (ventilation volume up to 80 $l{\cdot}min^{-1}$ and VO_2 up to 3.0 $l{\cdot}min^{-1}$) is presumably large enough for agricultural work tasks.

The OWAS method was chosen because reports of the method were available from ergonomic and rehabilitative studies in agriculture and forest work (Klen et al. 1991, Väyrynen & Könönen 1991, Pinzke 1994, Scott & Lambe 1996) and the computerized system made quick analyses possible. The test-retest reliability of the method was presumably high because the same researcher made all the analyses. However, systematic error was not eliminated.

The OWAS posture classification of upper limbs was inadequate because any part of the upper limb (hand, arm) could be at shoulder level in posture classes 2 and 3. Nevertheless, the strain of the shoulder muscles mainly depends on the posture of the upper arm (Nieminen et al. 1993). The leg classification did not separate squatting postures from the effective use of the legs (knee angle >150 degrees), which was especially taught during the occupationally oriented medical rehabilitation. The method was deficient when the work postures were classified into 4 action categories. The learned postures with a bent back and bent knees caused higher musculoskeletal load than the postures with bent back and straight knees. It was assumed that the OWAS method is not suitable for analyzing the work postures of physically disabled subjects who use an assistive mobility device, because the method does not take into account the symmetricity of work or support taken with hands.

The spinal load of lifting was quantified by static biomechanical modeling although the underestimation of the load was known when compared with dynamic modeling, which also takes into account the velocity and acceleration of the lift (Leskinen 1993). There were also advantages for this method, namely, the need for little information about the lift and the possibility to compare the results with reference values. In this study, several lifts performed by the subjects were unsuitable for analysis because the method could be used only for sagittal and symmetric lifts. The shape of the sack was uncomfortable, and many subjects lifted it with a bent and rotated back. The static back compression force of the men was higher after the course and after 1 year than n the prerehabilitation measurements; the difference was due to the increase in the horizontal distance between the sack and the feet of the subject. Thus, it is evident that dynamic aspects should be taken into account when lifting work is analyzed with biomechanical models.

Measurements of individual characteristics

The maximal exercise tests were carried out after a health examination by a physician, who also monitored the exercise tests. The exercise tests were performed with a bicycle ergometer. Cycling is suitable for workers' tests because it does not require high body control and coordination but it still activates the large muscle groups of the lower limbs as agricultural work does.

Two subjects whose leg had been amputated cycled with 1 leg. Cycling or arm cranking were feasible for the 4 disabled subjects because they could perform the test without interruption and the attained HRmax values were equal to the predicted values (ACSM 1995). In addition the maximal RPE values during the tests were 19-20. The amount of active muscle mass influenced the VO_2max, as Aminoff et al. (1996) also reported recently. However, no reports on maximal physical work capacity with 1-leg cycling compared with 2-arm cranking were found. Presumably, the physiological responses are equal when based on the estimated amount of active muscle mass in the tests.

The validity of the EMG test contraction of the shoulder muscles (shoulder elevation in a sitting position) has been tested by Westgaard (1988). However, it can be supposed that only a well-motivated and physically trained subject can produce maximal muscle forces. It is evident that the MVC values recorded for the occupational work situations in this study were not maximal.

Measurements of physical strain

In the HR measurements the use of the cardiotachometer with the transmitter and receiver permitted freedom of motion, which was important especially for disabled subjects, since the measurements were made during normal work situations. The rubber belt that formed the chest electrode was washable and resistant to perspiration. In this study, the HR monitor was put into the pocket of farmer's shirt or jacket during the measurements to avoid any voluntary influence on HR.

For persons with disabilities the HR and RPE methods have earlier been applied to evaluate perceived exertion and strain during exercise tests in the laboratory (Tahamont et al. 1986, Birk & Mossing 1988, Bhambhani et al. 1991, Hartung et al. 1993) or in daily activities (Janssen et al. 1994) but not in daily work situations.

The synchronized video EMG helped to identify and analyze the shoulder muscle activity in different work tasks. The trapezius muscles participate in almost any arm movement, and the load on the upper limbs was classified very roughly in the OWAS method. The mean EMG activity at work was compared with the MVC value, although it is known that muscle length has an effect on the maximal EMG value. The maximal EMG value was taken during a single MVC at 1 reference joint angle, and the mean EMG activity at work was measured in different dynamic tasks, which includes possibilities for several errors (Mirka 1991).

6.2 Effects of occupationally oriented medical rehabilitation (III, IV)

Traditionally, the effectiveness of medical rehabilitation has been evaluated by determining changes in physical and psychological capacity, perceived health and work ability, musculoskeletal symptoms, sick-leave days, and disability pensions (Härkäpää et al. 1990, Estlander et al. 1991, Leino et al. 1994, Holstila 1997) but seldom by determining changes in work techniques (Väyrynen & Könönen 1991). However, most occupationally oriented medical rehabilitation concentrates on training in ergonomic work techniques. The evaluation of the changes in work techniques, use of standardized analyzing methods, and systematic documentation increases the focus on ergonomics as an important part of rehabilitation.

This study showed that farmers could change their daily work techniques during the active work-oriented rehabilitation. These results agree with earlier data on loggers (Väyrynen & Könönen 1991). The development of the work techniques included the transfer of loads from the arms and back to the lower limbs, change of the grip of the work tools, symmetrical work movements, and the use of gravity and different work postures. In heavy work tasks, the use of a small muscle mass should be avoided due to the rapid development of local and general overstrain and fatigue. In this study the use of the poorest bent and twisted back postures decreased, although some of these postures obviously changed into the bent postures. A change in work techniques was evident, especially in milking. The subjects started using a milking chair or milked in the semi-kneeling posture recommended on the basis of biomechanical modeling and muscle activity measurements (Nemeth et al. 1990).

High peak forces were observed in the static postures of the beginning of manual heavy sack lifting. The mean value of the static peak compression exceeded the criterion of 3400 N (action limit) recommended for lumbar disc compression by the United States National Institute for Occupational Safety and Health (Waters et al. 1993) when men lift sacks of 30 kg from the floor or a level of 0.45 m using either the stoop or squat lifting technique. The back compression was equal to the results of Hagen (1990) concerning the biomechanical back compression of felling trees with an ergonomically "correct" work technique. Therefore, it seems that sacks (30 kg) cannot be lifted in a biomechanically acceptable way from the floor due to the adverse shape of the sack. The results agree with those of Leskinen (1993), who found only small differences in the effect on the spine between lifting techniques. When the stoop and squat lifting have been compared, higher VO_2 values have been reported for the squat than for stoop lifting at the same lifting frequencies (Welbergen et al. 1991), and lower peak compression was found at L5/S1 in squat lifting when a dynamic analysis was used (Leskinen et al. 1983).

During rehabilitation it would be useful to analyze the work processes that include lifting and try to determine ergonomic measures that minimize the strain in relation to the manual handling of heavy loads. Especially lifting from the floor should be decreased by means of environmental measures.

The musculoskeletal symptoms decreased in this study during the 1-year follow-up. The new work techniques included less back and shoulder load during work, and 1 explanation may also be the possible development of body control. The decrease in symptoms may also have been due to an increase in the skills of self-care, exercise breaks at work, and leisure-time physical exercise (Nevala-Puranen 1996).

The statistically significant increase in the WAI during the 1-year follow-up can indicate a lighter work load and better psychological resources. Tuomi et al. (1991a) showed that muscular work and poor work postures were the most impairing work stressors according to the WAI. These results concerning the WAI were better than in the study of Perkiö-Mäkelä (1996), which was based mainly on increasing physical exercise during the leisuretime of female farmers. However, it is important to note that another goal of the occupationally oriented medical rehabilitation program used was to develop the subjects' physical and psychological abilities (Leino et al. 1994, Nevala-Puranen 1996).

This intervention was carried out during the period when the possibility of joining the European Union was being debated very intensely in Finland. The possibilities to continue farming in the future may have also affected the motivation for rehabilitation and the subjective work ability. However, it is important that rehabilitation affects both work load factors and individual characteristics at the same time. Training of work techniques during occupationally oriented medical rehabilitation courses proved to be a feasible and effective action for reducing the undesirable physical work load of farmers.

6.3 Effects of environmental measures

6.3.1 Physical load and strain in milking (I, II)

In both the parlors and the tie stalls the milking was light or moderately heavy work (WHO 1978) for the cardiorespiratory system of the 11 subjects; this finding agrees with previous results (Tomlinson 1970, Vos 1974, Ahonen et al 1990). There was a discrepancy between the aerobic strain (%VO_2max) and cardiac strain (%HRR) for milking in the parlors and tie stalls. For the parlors the results showed a smaller increase in %VO_2max than in %HRR, whereas the reverse was true for milking in tie stalls. The difference may be due to a different kind of muscular effort (static versus dynamic), combined with higher mental stress, when the subject must control the milking of several cows at the same time in a parlor. The highest strain according to %VO_2max occurred for the women during milking in tie stalls without a rail system (study I).

The milking in parlors included fewer bent or bent and twisted back postures or squatting postures than the milking in tie stalls. Nemeth et al. (1990) and Svensson et al. (1985) have also reported lower biomechanical load on the low back, hips and ankles during milking in straight trunk postures. In the parlors there were slightly more postures with arms over the shoulder level than in the tie stalls, and this result may be due to too deep a parlor in relation to the milker's height and also due to the work technique used.

The shoulder muscle strain during milking in parlors was low (II), and this finding agrees with previous results (Arborelius et al. 1986). The milking work lasted 1-2 h per time and contained only short static work periods, like mounting the milking units and cleaning the udder. The shoulder muscle strain was low, partly because milking in parlors did not require the lifting or moving of heavy materials. The trapezius muscles were activated slightly asymmetrically because the subjects connected the milking units with their right hand, except for subject K (II) who was left handed. The highest EMG value occurred for subject G (II), who massaged cows' udders during the milk flow. In subject I (II) the %MVC of the left trapezius was higher than that of the right because his maximal isometric force on the left side was about the half that of the other side. It would be important to use milking units that are as light as possible and pay attention to the suitable depth of the parlor (about 50% of the height of the milker). In normal milking routines it is also possible to take short relaxation pauses and exercise breaks during the milk flow.

The use of a rail system in the tie stalls (I) decreased the milking time per cow because all the milking equipment could be transferred to the barn at the same time and the equipment was available near the milker the entire milking time. However, also other factors affected the change in work time. When the rail system was installed, other environmental or organizational changes were also made which could not be controlled. The installation of new milk tubes and taps speeded up the milk flow from the milk units to the cooler and the automatic removal system for the milking units on farm 2 reduced the work time. The number of cows in the first and second measurements differed. Lundqvist (1988) and Alakruuvi (1996) have shown that the milking time per cow is shorter with a greater number of cows. On 1 farm the subjects had also reorganized the milking process before the second measurement. This study showed that the use of a rail system in tie stalls decreased milking time per cow, which is important when the number of cows is increased.

The musculoskeletal load of milking was less in parlors than in tie stalls. However, in parlors, there were level differences and the work required stair climbing and moving among cows. Therefore, milking in parlors is difficult for farmers with physical disabilities. Despite the continuing decrease in the number of small farms with tie stalls, there will still be a fair number of farmers continuing to milk tied cows in the traditional manner for several decades. The use of a rail system in tie stalls decreased the postural load and milking time per cow. Thus the installation of a rail is a suitable environmental measure for farms where the postural load of farmers should be decreased or the number of cows will be increased. The cost of the rail is under 1000 Finnish marks per cow depending on the equipment. The rail system should be used in all possible work tasks, like transporting a newborn calf, calf milk, and straw, to reduce manual materials handling and to prevent slipping accidents. The postural load in tie stall milking can also be decreased by the use of a milking chair, milking carts and tables in the milkroom.

6.3.2 Physical strain of farmers with physical disabilities (V)

Little attention has been paid to ergonomic factors in the development of the work possibilities for farmers with disabilities, and only few reports were found on this topic (Field & Tormoehlen 1985, Field & Hancock 1989, Petrea et al. 1996). There are many factors in farming that make work possible for physically disabled persons, for example, the independence of the work, the possibilities to mechanize many work tasks, the lack of need to commute to work, and the traditional assistance of family members and neighbors. Agricultural work also includes many tasks impossible for disabled persons. Milking is infeasible because of the difficulty to move quickly away from a sitting or kneeling posture if a cow unexpectedly moves. Rapid movements are needed also in the transfer of animals. In addition, walking on uneven land (e.g., in the forest), manual handling of materials, and operating or repairing machines were considered to be impossible by the disabled subjects in this study.

The subjects themselves had taken environmental measures. These measures were mainly applied to the tractor, as in the study of Field & Tormoehlen (1985). However, there were still many environmental problems which made the work difficult, asymmetric and physically strenuous. Particularly in the transfer of loads, the utilization of carts would have both increased safety and symmetricity and decreased manual materials handling. Furthermore, there were many thresholds and differences in floor levels which made moving with a prosthesis or crutches difficult.

According to the %VO_2max the work was light or moderate for the cardiorespiratory system of 2 subjects, but another 2 subjects had heavy or very heavy work 31% and 4% of the studied work time, respectively. The high proportion of heavy work by subject M was partly due to his low (14.7 $ml \cdot kg^{-1} \cdot min^{-1}$) cardiorespiratory capacity. Subject N perceived his work as the lightest (RPE 7) because, after delivering flour, he stood and inspected for about 1 h. The mean activity of the trapezius muscles was 0.4-9% of MVC in different work tasks, which is below the upper limit recommended for dynamic muscular work (Jonsson 1988).

This study showed that long work experience and high motivation can compensate for major lacks in physical capacity. Physical disabilities require individually tailored environmental measures. Therefore, it is important that information on assistive agricultural technology be provided for planners of work tools and machines, occupational health care and rehabilitation personnel.

6.4 Future needs for research

In the future, due to the general ageing of the population and the work force, more and more persons with musculoskeletal disorders or physical disabilities will be working. All kinds of activities supporting workers' work ability should be developed. Controlled studies are needed to evaluate the effectiveness of different rehabilitation models, and, especially, a cost-benefit analysis should be made. It would be interesting to assess whether it is possible to change workers' work techniques in group "activities" organized as a part of occupational health services. In agriculture, it would be necessary to know the effects of mechanization on physical load and strain in different farm operations. The validity, reliability, and feasibility of work physiological methods (e.g., HR, RPE, EMG, work posture analysing methods) should be tested, and a standardized ergonomic analyzing system is needed for the work of persons with physical disabilities.

SUMMARY

In the future, the number of farmers will decrease, farms will become larger and the level of mechanization will increase in Finland. Dairy farms, where milking constitutes a major part of the daily work routine, will presumably remain the most important type of farm. Musculoskeletal disorders are the primary cause of work disability among farmers. The disorders have been shown to be associated with various physical work load factors. The results obtained in actual and simulated work tasks show that the postural load is high and cardiorespiratory strain is light or moderate in many work tasks. Hard work, according to cardiorespiratory strain, is found in forest work, in female farmers' tasks on dairy farms, and in lowly mechanized work tasks. Ergonomic measures are accentuated due to physical load factors, the large number of female workers, ageing, musculoskeletal disorders and permanent disabilities.

The aim of this study was to assess the effects of occupationally oriented medical rehabilitation and environmental measures on dairy farmers' physical work and ergonomics. This aim was attained with 5 studies. The physical load, strain, and work pace of milking in tie stalls and parlors were quantified in 2 case studies (I, II). The effect of occupationally oriented medical rehabilitation on farmers' work techniques, musculoskeletal pain and work ability was determined in 2 intervention studies (III, IV), and 1 case study (V) described the physical strain of farmers with physical disabilities.

The subjects, aged 26-53 years, were experienced farmers. In study I, the subjects were 2 male and 3 female farmers from 3 dairy farms with tie stalls. Three male and 3 female farmers from 5 dairy farms with milking parlors participated the study II. The subjects had had neck and shoulder symptoms during the previous year. In studies III and IV the subjects were farmers with low back or neck and shoulder pain that decreased their work ability; there were 27 female farmers in the study III (also in study IV) and 43 male and 52 female farmers in study IV. In study III the subjects participated in 4 occupationally oriented medical rehabilitation courses, lasting 3 weeks, organized by the Social Insurance Institution in 1 Finnish rehabilitation center; in study IV the number of courses was 10 organized in 3 rehabilitation centers.

In study V the subjects were 4 male farmers who had a physical disability due to a work or traffic accident. The disability required the use of an assistive mobility device (i.e., prosthesis or crutches) during work.

Information on work methods, daily work tasks, work tools and machines, health status, and the restrictions due to disability was obtained in interviews. The load factors were analyzed by measuring the oxygen consumption, work postures, L5/S1 disc compression force, and work pace of the subjects. Individual characteristics were assessed from measurements of body mass index, maximal oxygen consumption, maximal heart rate, resting heart rate, and maximal voluntary contraction of shoulder muscles. The musculoskeletal pain was analyzed with the pain lines and the perceived work ability was determined with the use of the work ability index. The indicators of strain were quantified by the percentage of maximal oxygen consumption, heart rate, the percentage of heart rate range, muscular strain, and perceived exertion.

Milking was light or moderate work for the cardiorespiratory system both in the tie stalls and in the parlors. Bent and twisted back postures accounted for 29% of the milking time in the tie stalls without a rail system, 10% in the tie stalls with a rail system, and 1% in the parlors. The work postures with one or both arms at or above shoulder level were the most typical in the parlors. However, the muscle activity in parlor milking was 2-8% of the maximal voluntary isometric contraction. The use of the rail system in the tie stalls decreased the harmful back postures and increased the work pace.

Occupationally oriented medical rehabilitation courses changed the farmers' work techniques in 3 daily work tasks (milking, handling ensilage, cleaning cows or floors) during a 1-year follow-up. Farmers worked with a bent and twisted back and arms at or over the shoulder level less after 1 year than before the rehabilitation. The training of lifting techniques did not decrease the biomechanical load of the back when sacks of 20 or 30 kg were lifted. The subjects had less musculoskeletal pain and better work ability after the 1-year follow-up than before the rehabilitation.

Among the farmers with physical disabilities (leg amputation, paraplegia) the mean aerobic strain was light (22% of maximal oxygen consumption) for 1 subject and moderate (30-46% of maximal oxygen consumption) for 3 subjects. Work tasks that were impossible due to the disability were milking, handling heavy materials, transferring animals, difficult operating and repairing tasks, and forestry work. All the subjects had made environmental measures due to the disability, and the measures were mainly directed towards the tractor.

The validity and reliability of the work physiological methods used were known to be high, and the methods complemented each other in describing different aspects of physical load and strain at work. The 3 case studies (I, II, V) including 4-6 subjects gave descriptive data which cannot be generalized. In studies III and IV the results can be generalized to farmers participating in occupationally oriented rehabilitation courses. Occupationally oriented medical rehabilitation courses and environmental measures (e.g., rail system, parlor) proned to be feasible ways to develop physical work and ergonomics in dairy farmers.

YHTEENVETO

Suomen maatalouden rakenteelliset muutokset jatkuvat; maatalousyrittäjien määrä vähenee, tilojen koko kasvaa ja koneellistuminen lisääntyy. Lypsykarjatalous säilynee edelleen tärkeimpänä tuotantosuuntana ja niillä tiloilla lypsytyö muodostaa pääosan päivittäisestä työstä. Tuki- ja liikuntaelinvaivat ovat tärkein syy maatalousyrittäjien työkyvyttömyyseläkkeelle siirtymiseen. Simuloiduissa ja todellisissa työoloissa tehtyjen tutkimusten mukaan useat maatalouden työtehtävät kuormittavat tuki- ja liikuntaelimiä ja ovat verenkiertoelimistön kuormittumisen perusteella kevyitä tai keskiraskaita. Verenkiertoelimistön kannalta raskaita tehtäviä ovat miehille metsätyöt ja naisille lypsykarjanhoitotyöt.

Tutkimuksen tavoitteena oli selvittää ammatillisesti syvennettyjen lääketieteellisten kuntoutuskurssien (ASLAK) ja työympäristöön kohdistuvien toimenpiteiden vaikutusta lypsykarjatilallisten maatalousyrittäjien fyysiseen työhön ja ergonomiaan. Tutkimus sisälsi 5 hanketta, joissa selvitettiin lypsytyön fyysisiä kuormitustekijöitä, työssä kuormittumista ja työhön kuluvaa aikaa työskenneltäessä joko parsi- ja pihattonavetassa (I, II), ammatillisesti syvennettyjen kuntoutuskurssien vaikutuksia maatalousyrittäjien työtekniikkaan (työasennot, nostotekniikka), tuki- ja liikuntaelinten kipuoireisiin ja työkykyyn (III, IV), sekä liikuntavammaisten maatalousyrittäjien fyysistä kuormittumista päivittäisessä työssä (V).

Koehenkilöt olivat 26-53 -vuotiaita kokeneita maatalousyrittäjiä. Tutkimuksessa I koehenkilöinä oli 2 miestä ja 3 naista 3 lypsykarjatilalta. Tiloilla oli parsinavetta, johon asennettiin lypsykiskojärjestelmä ensimmäisten tutkimusmittausten jälkeen. Tutkimukseen II osallistui 3 miestä ja 3 naista 5 lypsykarjatilalta, joilla oli pihattonavetta ja lehmät lypsettiin lypsyasemalla. Tutkimuksessa III oli mukana 4:lle Kansaneläkelaitoksen järjestämälle ASLAK-kurssille 1 kuntoutuslaitoksessa osallistuneet 27 naista. Tutkimuksessa IV oli 43 miestä ja 52 naista, jotka osallistuivat 10 ASLAK-kurssille 4 kuntoutuslaitoksessa. Tutkimukseen III osallistuneet olivat mukana myös tutkimuksessa IV. Tutkimukseen V osallistui 4 maatalousyrittäjämiestä, joilla oli työtapaturman tai liikenneonnettomuuden aiheuttama liikuntavamma (alaraaja-amputaatio, alaraajahalvaus) ja he käyttivät työssään alaraajaproteesia tai kyynärsauvoja.

Tutkimuksessa selvitettiin työn fyysiset kuormitustekijät, koehenkilöiden yksilölliset ominaisuudet ja työssä kuormittuminen. Haastattelulla selvitettiin työmenetelmät, päivittäiset työtehtävät, käytettävät työvälineet ja koneet, terveydentila ja liikuntavamman aiheuttamat rajoitukset työssä. Työn kuormitustekijöitä selvitettiin mittaamalla elimistön hapenkulutus, analysoimalla työasennot ja L5/S1-välilevyyn kohdistuva puristusvoima nostettaessa säkkiä, ja mittaamalla työhön kuluva aika. Koehenkilöiden yksilöllisiä ominaisuuksia arvioitiin kehon painoindeksin, maksimaalisen hapenkulutuksen, maksimisykkeen, leposykkeen ja hartialihasten maksimaalisen lihasaktiivisuuden mittauksilla. Liikuntaelinten kipua selvitettiin kipujanoilla ja koettua työkykyä työkykyindeksillä. Työssä kuormittumista selvitettiin määrittämällä elimistön suhteellinen hapenkulutus, syke, suhteellinen syke, hartialihasten suhteellinen aktiivisuus ja koettu kuormittuminen.

Lypsytyö oli verenkiertoelimistön kannalta kevyttä tai keskiraskasta työtä sekä parsi- että pihattonavetoissa. Selän kumaria ja kiertyneitä työasentoja oli parsinavetassa ilman kiskomenetelmää lypsettäessä 29 % ja kiskomenetelmää käytettäessä 10 % tutkitusta työajasta. Lypsyasemalla lypsettäessä vastaavia selän asentoja oli 1 % tutkitusta ajasta. Työasentoja, joissa toinen tai molemmat yläraajat olivat hartiatasolla tai sen yläpuolella, oli enemmän lypsettäessä lypsyasemalla kuin parsinavetassa. Hartialihasten keskimääräinen kuormittuminen EMG-mittausten perusteella oli lypsyasemalla työskenneltäessä 2-8 % maksimaalisessa isometrisessä supistuksessa tuotetusta lihasaktiivisuudesta. Kiskomenetelmän käyttöönotto parsinavetassa vähensi selän kuormittavia työasentoja ja lypsytyöhön kuluvaa aikaa.

ASLAK-kurssit muuttivat maatalousyrittäjien työtekniikkaa päivittäisissä työtehtävissä (lypsytyö, säilörehun käsittely, lehmien tai lattioiden puhdistus) vuoden seuranta-aikana. Tutkittavat työskentelivät selkä kumarassa ja kiertyneessä asennossa tai yläraajat hartiatasolla tai sen yläpuolella vähemmän vuoden seurannassa kuin ennen kuntoutusta. Nostotekniikan harjoittelu ei vähentänyt selän biomekaanista kuormitusta nostettaessa 20 tai 30 kg:n painoisia säkkejä. Tutkittavilla oli vähemmän liikuntaelinten kipua ja parempi koettu työkyky vuoden seurannassa kuin ennen kuntoutusta.

Liikuntavammaisten maatalousyrittäjien työ oli verenkiertoelimistön kuormittumisen perusteella pääasiassa kevyttä tai keskiraskasta. Tutkittavat eivät vammansa takia pystyneet lypsämään, käsittelemään raskaita taakkoja, siirtämään eläimiä, tekemään vaativia huolto- ja korjaustöitä eivätkä tekemään metsätöitä. Jokainen tutkittava oli tehnyt vammansa takia muutostöitä työympäristöön erityisesti traktoriin.

Useimpien tutkimuksessa käytettyjen työfysiologisten menetelmien validiteetti ja reliabiliteetti oli hyvä ja eri menetelmät täydensivät toisiaan kuvaten monipuolisesti työn kuormitustekijöitä ja työssä kuormittumista. Tapaustutkimusten (I, II, V) kuvailevaa tietoa ei voida yleistää. Tutkimusten III ja IV tulokset ovat yleistettävissä kaikkiin ASLAK-kuntoutukseen osallistuviin maatalousyrittäjiin. ASLAK-kuntoutuksella ja työympäristöön kohdistuvilla toimenpiteillä pystyttiin kehittämään lypsykarjatilallisten maatalousyrittäjien työn ergonomiaa.

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ORIGINAL PAPERS

I

Rail system decreases physical strain in milking

by

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Case study

Rail system decreases physical strain in milking

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Abstract

The physical strain of milking can be reduced by improving work methods. The aim of this study was to investigate the influence of the rail system (Alfa Line) on the physical strain and work time in tie stall milking. The measurements were performed before the installation of the rail system and after the one year of using the system. The subjects were two male and three female farmers (age 42 ± 2.1 years, mean $\pm$ *SD*), working daily in their barns. The mean heart rate (HR) and heart rate range (HRR) of the four subjects was lower when milking with the rail system. The simultaneous bent and twisted back postures decreased from 29.1% to 10.6% ($p < 0.05$). Postures with the arms held above shoulder level were reduced to about a half. The proportion of standing with both legs straight increased and squatting postures diminished in milking with the rail system. The mean milking time per cow was 3.8 min with the traditional machine milking method and 2.9 min with the rail method. This technical equipment reduced especially the musculoskeletal load in tie stall milking.

Relevance to industry

The results of this study can be taken into account when improving the work methods and work tools for machinery milking.

Keywords

Agricultural work; Milking; Ergonomics; Work posture

1. Introduction

Despite automation, agricultural work still includes many physically heavy work phases. The physical strain of agricultural work has been considered a problem in many international studies (Havel and Zimova, 1981; Lundqvist and Gustafsson, 1987; Stål and Pinzke, 1991). The handling of hay and forage and the removal of manure were the most strenuous on the circulatory system. The proportional oxygen consumption (%VO_2 max) of female farmers is over 50% in most work phases of dairy farming (Ahonen et al., 1990). Static forward bent postures and the lifting of heavy loads are very common in milking.

Farmers very often have musculoskeletal symptoms, especially in the back and neck (Gustafsson, 1990). The back problems of farmers have been found to be associated with material handling, whole body vibration and forward bent postures (Penttinen, 1987). In the milking procedure, the mounting of the milking unit loads the musculoskeletal system considerably. The mechanical load on the major joints of the body in different work postures has been described (Arborelius et al., 1986; Ekholm et al., 1985; Nemeth et al., 1990). Also the vertical and horizontal distances between the milker and the cow have to be taken into account in the ergonomics of milking (Nemeth et al., 1990). In this study, we

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show how the rail system changes the physical strain and work time in tie stall milking.

2. Material and methods

2.1. Subjects

The subjects were two male and three female farmers (aged 42 ± 2.1 years, mean ± *SD*) from three farms in eastern Finland. The subjects took part daily in the milking. The mean height of the subjects was 1.72 m (range 1.63 to 1.88 m) and mean weight 75.2 kg (range 68 to 84 kg). According to their body mass index (BMI, kg/m^2) the subjects were not overweight. The mean VO_2 max of the subjects was 34.7 ± 3.3 $ml \cdot min^{-1} \cdot kg^{-1}$ in the first measurement and 32.6 ± 4.2 $ml \cdot min^{-1} \cdot kg^{-1}$ in the second measurement.

2.2. Farms

The three farms studied (Table 1) were the first ones in eastern Finland to install the rail system. Before acquiring the rail system the subjects milked with traditional machine milking methods. Subjects 3 and 4 carried their milking equipment from the milkroom to the barn (Fig. 1) and the other subjects moved them with a milking cart (Fig. 2). Subjects 1 and 2 used a milking chair during milking. In the rail system the milking units and other milking equipment were brought from the milkroom to the barns by pushing (Fig. 3).

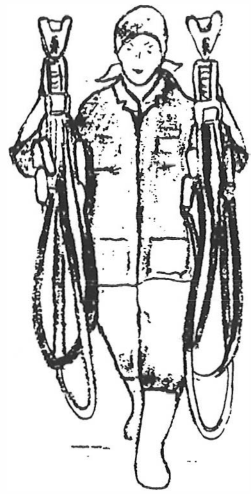

Fig. 1. The typical way of carrying the milking units.

Table 1

The number of milked cows per subject and the number milking units per farm in the first (I) and second (II) measurements

	Milked cows		Milking units	
	I	II	I	II
Farm 1			3	4
Subject 1	12	12		
Subject 2	10	10		
Farm 2			4	5 [a]
Subject 3	12	20 [b]		
Subject 4	12	20 [b]		
Farm 3			6 [a]	6 [a]
Subject 5	29	32		

[a] Automatic stopping of milking and removing of milking units
[b] Work division between the subjects was different in the first and second measurements

2.3. Methods

The measurements were performed before the installation of the rail system and one year later. The measurements in the laboratory and at work were performed similarly in both years. The direct maximal oxygen consumption (VO_2 max) of the subjects was measured by the maximal bicycle

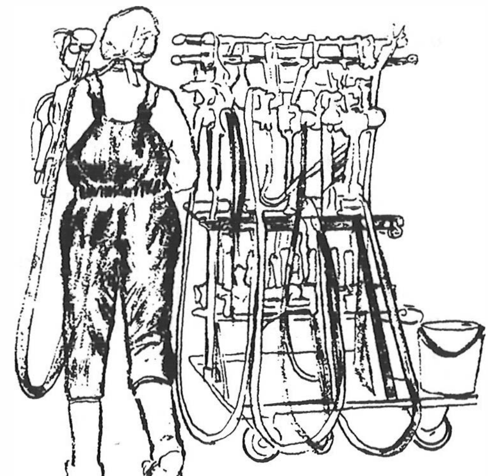

Fig. 2. Milking cart used to move milking units and other milking equipment.

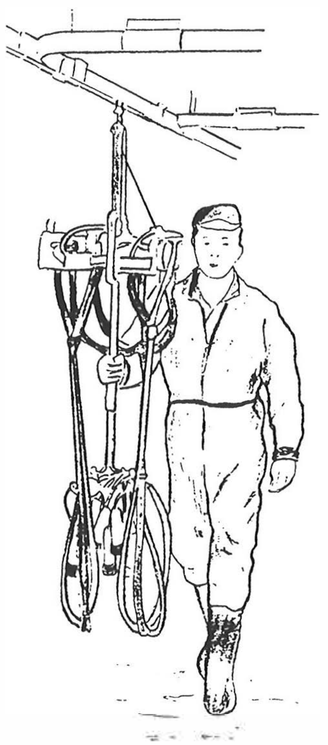

Fig. 3. In the rail system, the milking units and other milking equipment are transferred by pushing.

ergometer test with a breath-by-breath respiratory gas analyser in the laboratory (Arstila et al., 1984). Other measurements were performed in the farmers' own dairy barns during one evening work shift.

Oxygen consumption during milking was measured with a portable Morgan Oxylog device in 20-min measuring periods (Harrison et al., 1982). Heart rate was measured by minutes during the whole evening work shift with a Sport Tester PE3000 device (Polar Elektro, Finland). The heart rate range (HRR) was calculated with the equation: $(HR_{work} - HR_{rest})/(HR_{max} - HR_{rest}) \times 100$ (Karvonen et al., 1957).

The work postures were classified by the observational basic OWAS method (Louhevaara and Suurnäkki, 1992). The positions of the back and the upper and lower limbs were observed and the force used was estimated every 30 seconds. The number of observations with the traditional milking method was 615 and with the rail system 641. The OWAS method classifies combinations of these four subfactors by the degree of difficulty for each posture combination. The degree of difficulty is ranked into action categories, indicating the need to change the posture. The observations were recorded in the memory of a Micronic data collection device and then transferred to a computer. The rate of perceived exertion (RPE) was inquired with the Borg scale every five minutes (Borg, 1970).

The total work time of the evening work shift and the average milking time were measured with a stopwatch continuously. The duration of different work phases was measured with a stopwatch using the reset method with 0.01 min accuracy.

3. Results

The mean heart rate (HR), the heart rate range (HRR) and the rate of perceived exertion (RPE) were lower when milking with the rail system compared to the traditional method (Table 2). These changes were not statistically significant.

The proportion of loading work postures of the back decreased in milking with the rail system compared to milking with the traditional method (Table 3). Simultaneous bent and twisted back postures decreased from 29.1% to 10.6%, which was a statistically significant difference ($p < 0.05$). Similarly, postures with the arms above shoulder level were reduced to about a half. The proportion of standing with both legs straight increased statistically significantly ($p < 0.05$) and standing or squatting with one or both knees bent decreased.

Table 2

The physical strain (mean $\pm$ *SD*) in milking with the traditional method and the rail system (paired *t*-test)

Variable	Traditional method $n = 5$		Rail system $n = 5$
HR ($beats \cdot min^{-1}$)	96 $\pm$ 9.4	ns	90 $\pm$ 10.5
VO_2 ($l \cdot min^{-1}$)	0.8 $\pm$ 0.09	ns	0.8 $\pm$ 0.08
HRR (%)	29.2 $\pm$ 5.8	ns	22.6 $\pm$ 7.4
$\%VO_2$	32.2 $\pm$ 6.3	ns	33.2 $\pm$ 7.2
RPE (6–20)	11.2 $\pm$ 0.7	ns	10.8 $\pm$ 0.7

ns = not significant

Table 3

Distributions of postures (%) according to OWAS variables in milking with the traditional method and the rail system

Variable	Description	Traditional milking method $n = 5$		Rail system $n = 5$
Back	1. straight	40.3	ns	49.9
	2. bent forward, backward	27.5	ns	35.7
	3. twisted or bent sideways	3.1	ns	3.7
	4. bent and twisted	29.1	a	10.6
Arms	1. both arms below shoulder level	81.9	a	91.4
	2. one arm at or above shoulder level	14.5	ns	7.8
	3. both arms at or above shoulder level	3.6	ns	0.8
Legs	1. sitting	24.9	ns	26.7
	2. standing with both legs straight	21.6	a	36.0
	3. standing with one leg straight	6.8	ns	1.2
	4. standing or squatting with both knees bent	26.8	ns	13.9
	5. standing or squatting with one knee bent	1.6	ns	–
	6. kneeling on one or both knees	–	ns	0.3
	7. walking or moving	18.2	ns	21.8
Load/use of force	1. less than 10 kg or 100 N	98.0	ns	99.8
	2. 10–20 kg or 100–200 N	1.6	ns	0.2
	3. over 20 kg or over 200 N	0.3	ns	–
Action categories	1. no corrective measures	41.8	ns	52.6
	2. corrective measures in the near future	30.2	ns	34.3
	3. corrective measures as soon as possible	11.2	ns	10.0
	4. corrective measures immediately	16.7	ns	3.1

ns = not significant
[a] = $p < 0.05$

The most common work posture with the traditional milking method was a bent and twisted back and standing or squatting with both knees bent (Fig. 4). This posture belongs to action category four, in which corrective measures to improve the work postures should be taken immediately. In the two most common work postures with the rail system, the back was straight and the subject was standing with straight legs or walking.

The total milking time with the traditional method was 64 min and with the rail system 59 min. Milking with the rail system decreased the average milking time per cow of four subjects compared to milking with the traditional method (Table 4). The average milking time (total time minus rest, interruption and other work) of the subjects was 49.5 min (range 41.6–55.6) with the traditional method and 47.3 min (range 38.3–56.8) with the rail system. Shortened milking times in the different work phases were most common in

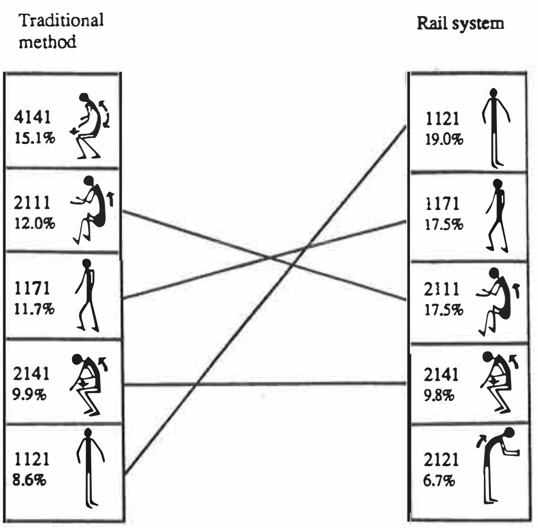

Fig. 4. The five most common work postures according to the OWAS classification in milking with the traditional method and the rail system. Each box shows the posture, the OWAS code and the percentage of observations made.

Table 4

The mean milking time (min) per cow with the traditional method and the rail system

Subject	Milking time (min)	
	Traditional method	Rail system
1	3.9	4.0
2	5.6	3.8
3	3.5	2.2
4	4.5	2.8
5	1.7	1.6
Mean	3.8 [a]	2.9

[a] = $p < 0.05$

preparing for the milking, massaging the udder, and mounting the milking unit.

4. Discussion

This case study showed that the rail system decreased physical strain especially of the loading work postures in tie stall milking. The influence of the rail system on work time was minor.

Also other aspects than the rail system affected the results of physical strain and work time in milking. The traditional work method, the rail method, and the amount of subjects' work was different on each of the three farms studied. At the time the rail system was installed, other changes had also been undertaken, which influenced the results. The installation of new milk tubes and taps speeded up the milk flow from the milk units to the cooler. The automatic removing system of the milking units on farm 2 reduced work time and loading work postures in the removing of the milking units.

The difference in the number of cows in the first and second measurements influenced the results of work time. Only on farm 1 the subjects milked the same number of cows. On farm 2 the subjects' division of work was different in the first and second measurements. The milking time of a cow can vary from one occasion to another for many reasons. The amount of milk was not measured in this study.

The physical strain (HR, HRR, VO_2) of four subjects was less with the rail system compared to the traditional method. The proportional oxygen consumption (%VO_2 max) was higher with the rail system compared to the traditional method, because the VO_2 max of the subjects decreased during the study year. The rate of perceived exertion was the same or lower in milking with the rail system compared to the traditional method, although the work time per cow was shorter.

The rail system did not much change the oxygen consumption (VO_2) in comparison with the traditional milking method. This is because in the traditional milking method three subjects transported milking units and other equipment with the milking cart. The lifting of heavy loads was minimized also before taking the rail system into use.

According to this case study, milking with the rail system decreased physical strain and work time in tie stalls. Milking with the rail system cut down especially loading work postures. The use of the rail system and a milking chair is a good way of reducing musculoskeletal load in milking. The system can also be used for transporting a newborn calf, calf milk, and straw, and thus decrease heavy lifting in agricultural work.

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II

Physical load and strain in parlor milking

by

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Physical load and strain in parlor milking

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Abstract

Due to the structural developments in Finnish agriculture, milking in milking parlors has become more common. The purpose of this study was to analyze physical work load and strain when milking in a parlor. The study group consisted of three male and three female farmers aged 35–45 years. The measurements were done in the field in their own parlors during one morning work period lasting about two hours. The physical load and strain of milking was analyzed by measuring oxygen consumption (VO_2), heart rate (HR) and muscle activity (EMG) of the upper trapezius muscles by ambulatory measuring devices. The rate of perceived exertion was estimated and the postural load was evaluated with the Ovako Working posture Analysing System (OWAS). Milking in parlors was found to be mostly light work with a low VO_2 (0.6 l/min) and HR (95 beats/min). The subjects worked 85% of the time with a straight back and 76% of the time with both arms under shoulder level. The mean activity of the trapezius muscles was 2–8% of the maximal voluntary isometric contraction (%MVC) on the right side and 2–6% on the left side. Milking in parlors can be considered as light work for the cardiorespiratory and musculoskeletal system.

Relevance to industry

The information of this study can be utilized in the development of the working environment of milking.

Keywords: Agriculture; Oxygen consumption; Heart rate; OWAS-method; Electromyography

1. Introduction

Because of the current rapid structural development in Finnish agriculture the size of dairy farms is getting larger. Musculoskeletal disorders are common in farmers, and particularly their back problems are associated with manual materials handling, whole body vibration and forward bent work postures i.e. in milking (Penttinen, 1987). Therefore it is important to study if the new milking methods have changed the high physical work load (Ahonen et al., 1990, Németh et al., 1990).

In Finland there are two main types of milking techniques, i.e. milking in tie stalls and milking in parlors. In tie stall milking, which still is the most common way of milking, the cows are tied in place. The farmer moves all the needed milking equipment from one cow to another and, when milking the cow, has to squat, kneel or sit (Fig. 1). In parlor milking, the worker is able to stand with a straight back as the

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Fig. 1. A typical work posture when milking in a tie stall.

cows are located on a higher level than the milker (Fig. 2).

In tie stall milking, the oxygen consumption (VO_2) is 32 and 51% of the maximal VO_2 for male and female farmers respectively ($n = 18$) (Ahonen et al., 1990). According to another study of tie stall milking (Nevala-Puranen et al., 1993), the mean VO_2 was 32% of the maximal VO_2 and the relative range of heart rate (HR) was 29% ($n = 5$). The subjects worked 60% of the milking time with the back bent forward, twisted or simultaneously bent and twisted. Even after a rail system was installed and used to transfer the milking units, the subjects still worked with the same poor back postures 50% of the time.

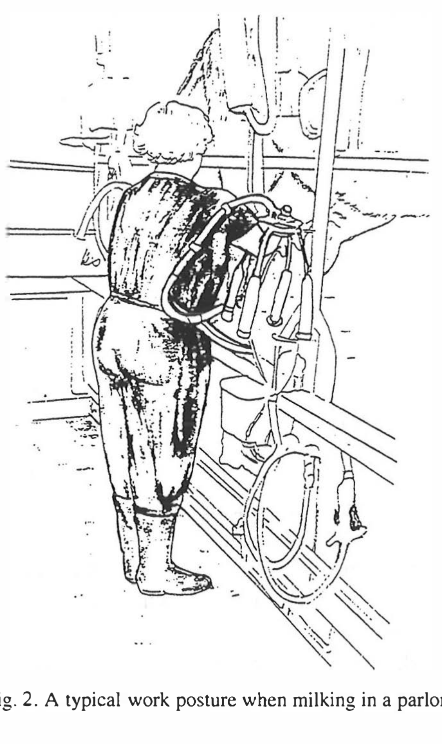

Fig. 2. A typical work posture when milking in a parlor.

When compared to a straight posture of the trunk, working in a stooped posture results in higher values for compressive forces on the vertebral discs, tension of the back muscles, HR, VO_2, and ratings of discomfort and fatigue (Chaffin and Andersson, 1984; Morrissey, 1987). Also the ability to produce maximal forces is reduced because of the poor work postures of the back (Mital, 1986).

The postural load of different milking methods has been studied in a laboratory. One study of Arborelius et al. (1986) showed that the mounting of the milking unit set a high load on the musculoskeletal system in particular. The biomechanical load on the major joints of the body in different work postures has been described during milking (Ekholm et al., 1985; Németh et al., 1990). The main environmental factors affecting the postural load are the vertical and horizontal distances between the milker and the cow (Németh et al., 1990). The purpose of the present study was to quantify the physical load and strain of milking work when milking in a parlor. This study is part of a larger project on the work environment and methods in modern Finnish dairy farms.

2. Material and methods

2.1. Subjects

Three male and three female farmers (aged 35–45 years) who milked in parlors daily participated in the study. Their mean height and weight were 168 cm (range 155 to 185 cm) and 78 kg (range 55 to 102 kg). According to the body mass index (BMI, kg/m^2) two of the subjects were overweight because their BMI was over 27 kg/m^2 (Ross and Marfell-

Jones, 1991). The subjects' mean VO_2max was 2.6 l/min (range 1.9 to 3.5) which was 33.4 (range 25.1 to 39.2) ml/min/kg when the body weight was taken into consideration.

2.2. Farms

The subjects worked on five modern farms located in the eastern Finland (Table 1). The cows were milked in parlors in which it was possible to milk 4–5 cows at the same time (Fig. 2). In every farm there were an automatic removal system of the milking units. One male farmer milked alone, one female farmer had some help when gathering the cows before milking and the others worked with another member of the family.

2.3. Methods

The maximal VO_2 of the subjects was measured in a laboratory using the direct maximal bicycle ergometer test with a respiratory gas analyser (Oxycon Minjhard). Other measurements were performed at worksites during one morning work period which mostly included work related to milking. The milker gathered the cows, cleaned the cows' udder, took test sprays of milk, connected the milking units, observed the milk flow, creamed the cows' udder and washed the parlor.

The milking units were weighed and the vertical depth of each parlor was measured. Oxygen consumption was measured with a portable Morgan Oxylog device (Morgan Ltd, England) which was calibrated in the laboratory with the Oxycon Minjhard before the measurements. The average measuring time of VO_2 was 18 min (range 12–31 min). HR was measured in 15 s intervals with a Sport Tester cardiometer (Polar Electro, Finland) the mean length of measurements being 115 min (range 97–140 min). The data was later transferred from the Sport Tester to a microcomputer and analyzed with the Polar Sport Tester analyzing program. The relative range of HR (%HRR) was calculated with the equation: $(HR_{work} - HR_{rest})/(HR_{max} - HR_{rest}) \times 100$ (Karvonen et al., 1957). The rate of perceived exertion (RPE) was asked every five minutes with the Borg scale rangeing from 6 to 20 (Borg, 1970).

The muscle activity (EMG) was recorded bilaterally from the descending parts of the trapezius muscles with a portable ME3000P device with a video option (Mega Electronics, Finland). The EMG was recorded by using the averaged mode, time interval of 0.1 seconds and bipolar setting of disposable surface electrodes (M-OO-S, Medicotest, Denmark). The inter-electrode distance was 20–30 mm and the electrodes were placed on the upper margin of the trapezius muscle at the midpoint between the acromion and the spinous process of the 7th cervical vertebrae. The reference electrodes were placed on the spinous processes of the 6th and 7th vertebrae. The EMG of the maximal voluntary contraction (MVC) was recorded during two maximal isometric constricted elevations of the shoulders. The maximal EMG amplitudes of the trapezius muscle varied from 245 to 959 μV on the left and from 499 to 885 μV on the right side. All farmers except for one (subject F) were right handed. The milking procedure was also video recorded with a Panasonic S-VHS-C video

Table 1
Description of the farms in the study

	Farm				
	1	2	3	4	5
No. of workers	1 (A)	2 (B, C)	1 (D)	1(E)	1 (F)
No. of cows milked	17	20	22	13	20
Duration of milking (min)	82	80 (subj. B) 85 (subj. C)	99	59	96
No. of milking units	5	4	4	4	4
Weight of milking unit (kg)	3.0	3.0	3.0	2.0	2.75
Depth of parlor (cm)	91	85	85	82	83

Table 2
The farmers' oxygen consumption (VO_2), relative aerobic strain ($\%VO_2max$), heart rate (HR), percentage of the heart rate range (%HRR), and the rate of perceived exertion (RPE) and mean values of parlor and tie stall milking (Nevala-Puranen et al., 1993)

Variable	Subject						Mean in parlors	Mean in tie stalls
	A	B	C	D	E	F		
VO_2 (l/min)	0.4	0.4	0.6	1.1	0.5	0.3	0.6	0.8
$\%VO_2max$ (%)	18	18	24	32	27	8	21	32
HR mean (beats/min)	101	90	96	90	100	91	95	96
%HRR (%)	26	25	30	16	30	15	24	29
RPE (6–20)	10	13	9	13	11	10	11	11

camera. The EMG data was transferred via optic link to a computer and then related to the MVC and the video recording of the work.

The work postures during 30 minutes of work were analysed with the OWAS method from still videotape frames every 10 seconds (Karhu et al., 1977; Louhevaara and Suurnäkki, 1992; Mattila et al., 1993). The OWAS method identifies four work postures for the back, three for the arms and seven for the legs. It also estimates the weight of the handled load or the amount of force used. The data was stored to a computer by using the OWAS collection program (OWASCO) and calculated with the OWAS analyzing program (OWASAN). The total number of observations was 2160. In the OWAS method the degree of the harmfulness of postural

Table 3
Proportion of OWAS work postures (%) of the milking time when milking in parlors compared to milking in tie stalls (Nevala-Puranen et al., 1993)

	Description	Milking in parlors ($n = 6$), %	Milking in tie talls ($n = 5$), %
Back	1. straight	85	40
	2. bent forward, backward	11	28
	3. twisted or bent sideways	3	3
	4. bent and twisted	1	29
Arms	1. both arms below shoulder level	76	82
	2. one arm at or above shoulder level	16	14
	3. both arms at or above shoulder level	8	4
Legs	1. sitting	10	25
	2. standing with both legs straight	66	21
	3. standing with one leg straight	1	7
	4. standing or squatting with both knees bent	2	27
	5. standing or squatting with one knee bent	–	2
	6. kneeling on one or both knees	–	–
	7. walking or moving	21	18
Load/use of force	1. less than 10 kg or 100 N	100	98
	2. 10–20 kg or 100–200 N	–	2
	3. over 20 kg or over 200 N	–	–
Action categories	1. no corrective measures	87	42
	2. corrective measures in the near future	10	30
	3. corrective measures as soon as possible	3	11
	4. corrective measures immediately	–	17

load is ranked into four action categories indicating the urgency to change the work posture. The results of this study have been presented as means, standard deviations and ranges.

3. Results

The mean VO2 was 0.6 l/min (range 0.3–1.1 l/min) and the mean HR varied from 90 to 101 beats/min during milking. Heart rate range was the highest for the subjects C and E (30%) whereas the oxygen consumption was the highest for the subject D (32%VO_2max). All farmers except for subject B considered the milking work to be very light or light i.e. 9–11 on the Borg scale. Subject B rated the work as moderately heavy (13 on the scale) (Table 2). Cardiorespiratory load and strain was lighter when milking in parlors compared to milking in tie stalls.

According to the OWAS analysis the subjects worked 85% of the milking time with straight back and 1% of the time with back bent forward and twisted simultaneously. The numbers in tie stall milking were 40% and 29% respectively (Nevala-Puranen et al., 1993). One or both arms were at or above the shoulder level in 24% of the working time at parlors compared to 18% in tie stalls (Table 3). At the parlors there were no postures requiring immediate corrective measures (action category four) and 3% of the postures required corrective measures as soon as possible (action category three).

The average EMG during milking in parlors was 2–8% MVC on the right and 2–6% MVC on left trapezius muscle (Fig. 3). Subject B had the highest EMG values on the right trapezius and her work load on the shoulder area was also the most asymmetrical.

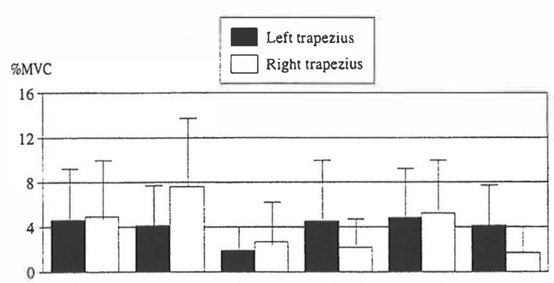

Fig. 3. The mean (SD) muscle activity (%MVC) on the right and on the left trapezius muscle during milking in a parlor.

4. Discussion

4.1. Methodological discussion

Although this study included only six subjects, the results can be considered reliable as the work load was related to the subjects' individual maximal physical capacity. In addition, the physical work load and strain of milking was analyzed from several aspects: cardiorespiratory, musculoskeletal and perceived load and strain. This study also confirmed that it is possible to measure many variables at the same time during actual work situation without disturbing the normal work routine.

The greatest inconvenience during the measurements was caused by the Oxylog device used to measure the VO_2. The face mask of the device disturbed mainly the social communication. The HR and EMG measurement devices did not cause a major disturbance. When measuring muscle activity during MVC in the field it is not always possible to activate a specific muscle maximally with only one test, hence the muscle activities during milking have to be considered as indicative. The OWAS method has been developed to analyze the postural load in static and dynamic work and is therefore suitable for evaluating of agricultural work. The computerized OWAS method allowed efficient data collection and rapid analysis of the data (Mattila et al., 1993).

4.2. Discussion of the results

Milking in parlors had lower cardiorespiratory load and strain than milking in tie stalls (Nevala-Puranen et al., 1993). In both cases milking can be considered as light or moderately heavy work for the cardiorespiratory system. The aerobic load according to the VO_2 was highest (1.1 l/min) in the case of subject D who had the greatest number of cows and also worked alone. Subject B had the highest rate of perceived exertion. According to the VO_2max her aerobic capacity was the lowest and she also was the most overweight.

This study confirmed that milking work in a parlor includes only few bent or bent and twisted back postures. The postures with arms over shouder level were partly due to too deep a parlor related to milker's height. The work technique also had influence on the arm postures as some subjects massaged the udder during milking. The postural load of milking was lower in the parlors than in the tie stalls (Nevala-Puranen et al., 1993).

Jonsson (1978) suggests that the mean load level should not exceed 10% of MVC and must not exceed 14% of MVC when the duration of the work is one hour or more. Since the average EMG of the trapezius muscles during milking was 2–8% of MVC on the right side and 2–6% of MVC on the left side, the work should not cause injuries for the shoulder–neck region. The static level during continuous long-term work should not exceed 2% of MVC and must not exceed 5% of MVC (Jonsson, 1978). Milking work lasted 1–2 hours per time and contained only short static work periods like mounting the milking units and cleaning of the udder. The shoulder muscle load was low partly because milking in parlors did not require lifting or transferring of heavy materials. The trapezius muscles were loaded slightly asymmetrically because the subjects connected the milking units with their right hand except for subject F who was left handed. The highest EMG value was in subject B who massaged the cows' udder during the milk flow. In subject D the %MVC of the left trapezius was higher compared to the right because his maximal isometric force on the left side was about a half of the other side.

An efficient way to further improve the working situation is to concentrate on the physical environment and the milking equipment. It is important to use as light a milking unit as possible. A suitable depth for the parlor is about 50% of the height of the milker. In the normal milking routine one should also maintain short resting pauses during the milk flow. It is possible that persons suffering from musculoskeletal disorders are more able to work safely in parlors than in tie stalls.

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III

Reduction of farmers' postural load during occupationally oriented medical rehabilitation

by

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Reduction of farmers' postural load during occupationally oriented medical rehabilitation

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Farmers' back problems may be associated with the amount of back flexion and the handling of heavy loads. The aim of this study was to analyse the effects of occupationally oriented medical rehabilitation courses on female farmers' postural load. Twenty seven female farmers (aged from 32 to 52 years) took part in four rehabilitation courses at one rehabilitation centre in Finland. The subjects suffered from various musculoskeletal symptoms, which decreased their work ability. The rehabilitation courses included two periods: the first lasted for 3 weeks and the latter for 1 week, organized 6 months after the first period. The work postures and their load on the musculoskeletal system were classified by the computerized OWAS method in three daily work phases. During the 3-week periods new work techniques were learned, and simultaneous bent and twisted postures for the back decreased from 34 to 4% of all studied work postures. Similarly, postures with one or both arms above shoulder level were reduced from 44 to 24%. Rechecking after the 6-month period confirmed that the adoption of new work techniques was consistent. The study showed that female farmers could change their work techniques during this kind of intensive rehabilitation period, and the changes were seen 6 months later in the follow-up.

Keywords: work posture, computerized OWAS method, agriculture

Low-back problems are common in farmers, and appear to be associated with the amount of postures requiring back flexion, carrying and lifting of heavy loads, and exposure to whole-body vibration (Penttinen, 1987). Even nowadays, very many physically heavy work phases and a combination of several stress factors, including poor work postures and use of force, are found in farmers' work in Finland. High postural work load is typical, especially in milking procedure, which includes stooped and kneeling postures (Arborelius *et al*, 1986). According to a case study (Nevala-Puranen *et al*, 1993), the farmer worked 60% of the milking time with his back bent or simultaneously bent and twisted. Ahonen *et al* (1990) have shown that the dynamic workload, ie, the relative aerobic strain (% VO_2max), of female farmers was over 50% in most work phases of dairy farming.

The amount and quality of forward-bent work postures and the techniques of manual materials handling influence the compressive forces on the vertebral discs and the electromyography of erector spinae muscles (Chaffin and Andersson, 1984; Leskinen, 1993). However, working in a stooped posture results in higher heart rates, metabolic load, and ratings of discomfort and fatigue (Morrissey, 1987). Mital (1986) has shown that the ability to produce maximal forces depends considerably on the work posture used.

Work postures can be primarily improved by changing individual work techniques, working environment, load characteristics, equipment and tools, or by organizing work better (Leskinen, 1993; Nevala-Puranen *et al*, 1993). Improvements in work postures demand motor learning, like all new motor tasks (Singer, 1980). Loggers were found to be able to change their work postures during occupationally oriented medical rehabilitation courses, and the new work techniques were maintained over the 4-year follow-up period (Väyrynen and Kōnönen, 1991). The aim of this study was to analyse the effects of occupationally oriented medical rehabilitation courses on female farmers' work postures and their postural load.

Material and methods

Subjects

The subjects were 27 female farmers (mean aged 42.9 years, sd 5.5), who took part in four occupationally oriented medical rehabilitation courses in one Finnish rehabilitation centre in 1992. All the subjects worked on dairy farms. Their mean height and weight were

163 cm (sd 6) and 72 kg (sd 11). According to the body mass index (BMI, kg/m^2), 48% of the subjects were slightly overweight (25 $\leq$BMI <30) and 26% were considerably overweight (BMI $\geq$30). The subjects suffered from various symptoms due to musculoskeletal disorders, which decreased their work ability.

Rehabilitation courses

The occupationally oriented rehabilitation courses for female farmers were developed and funded by the Social Insurance Institution in Finland. The main goals of the rehabilitation were to increase the subjects' physical and psychological capacity and to teach the subjects work techniques that optimize the load on the musculoskeletal system. The courses included training of ergonomically 'good' work techniques in a classroom and in actual work situations, physical activities, and learning of the structure and strain responses of the musculoskeletal system. The new work techniques were taught by a physiotherapist and a teacher of agricultural work. Each of the courses included two periods: the first period lasted for 3 weeks and the second for 1 week, held 6 months after the first.

Measurements before the courses	⇒	Occupationally oriented medical rehabilitation courses 3 weeks	⇒	Measurements after the courses	⇒	Measurements after 6 months

Figure 1 The rehabilitation process

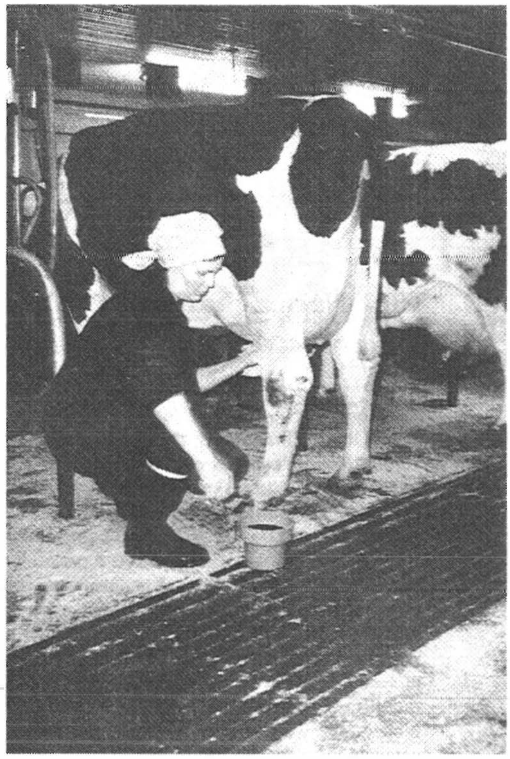

Figure 2 The studied work phases were milking, cow brushing and silage handling

Between the rehabilitation periods the subjects used the new work techniques in daily work routines at home.

Methods

The assessments of work postures and their load on the musculoskeletal system were performed at the beginning and at the end of the 3-week rehabilitation period and during the second period (ie after 6 months) (*Figure 1*). The work postures were videoed by a physiotherapist in three daily work phases (milking, cow brushing and silage handling) for 12 min in the same tie stall during the rehabilitation course (*Figure 2*). In each of the three video recordings the subjects were asked to work with the techniques that they would use at that time in their normal work routine.

The postural observations for the OWAS analysis were made by a researcher in a laboratory from still videotape frames every 10 s (Louhevaara and Suurnäkki, 1992; Mattila *et al*, 1993). The data were input into a computer using the OWAS collection program (OWASCO), and the total number of observations was 5593. The results were analysed using the computerized analysing programme (OWASAN).

The OWAS method identifies four work postures for the back, three for the arms and six plus walking for the legs, and estimates the weight of the load handled or the amount of force used. The method classifies combinations of these four categories by the degree of harmfulness for the musculoskeletal system of all posture combinations. The degree of the harmfulness of the combinations is ranked into the four action categories (*Table 1*), indicating the urgency for change.

Table 1 The OWAS action categories for work postures and posture combinations

Action category	Description
1	Work postures are normal. No actions are needed to change work postures.
2	Work postures may have a harmful effect on the musculoskeletal system. Action to change the posture should be taken in the near future.
3	Work postures have a harmful effect on the musculoskeletal system. Action to change the posture should be taken as soon as possible.
4	Work postures have a very harmful effect on the musculoskeletal system. Action to change the posture should be taken immediately.

Results

The proportion of strenuous work postures decreased in the three work phases studied during the 3-week period. Simultaneous bent and twisted back postures, which were considered the most strenuous, decreased from 34 to 4% (*Table 2*). Similarly, postures with one arm or both arms at or above the shoulder level were reduced to about a half. Also, sitting and kneeling postures in milking increased, and the subjects began to use milking chairs and knee protectors while milking. Rechecking after the 6-month period confirmed that the new work techniques had been adopted.

In all the five most typical work posture combinations (*Figure 3*) before the course, the back was bent or bent and twisted. After the course and in the 6-month follow-up the subjects most often worked with the back straight. Before the course the work posture combinations belonging to action categories 3 and 4 were most typical in milking (*Figure 4*). After the course the proportion of work posture combinations belonging to action category 4 was diminished in all three work phases, and the changes were still seen after 6 months.

Discussion

One goal of the occupationally oriented medical rehabilitation courses was to teach the female farmers work techniques that optimized the load on the musculoskeletal system, especially the back. This goal was achieved, as the bent and twisted back postures decreased from 34 to 4% of studied postures. The change of work postures and movements is difficult,

Table 2 Distributions of postures (%) according to OWAS variables before the rehabilitation courses, after the 3-week courses and after 6 months

Variable	Description	Before the course	After 3 weeks	After 6 months
Back	(1) Straight	22	48	56
	(2) Bent forward	31	46	38
	(3) Twisted or bent sideways	13	2	2
	(4) Bend and twisted	34	4	4
Arms	(1) Both arms below shoulder level	56	76	78
	(2) One arm at or above shoulder level	31	13	13
	(3) Both arms at or above shoulder level	13	11	9
Legs	(1) Sitting	3	7	10
	(2) Standing with both legs straight	53	41	43
	(3) Standing with one leg straight	4	2	1
	(4) Standing or squatting with both knees bent	27	23	21
	(5) Standing or squatting with one knee bent	1	–	–
	(6) Kneeling on one or both knees	1	11	7
	(7) Walking or moving	11	16	18
Load/use of force	(1) Less than 10 kg	100	100	100
	(2) 10–20 kg	–	–	–
	(3) Over 20 kg	–	–	–
Number of observations		1944	1945	1704

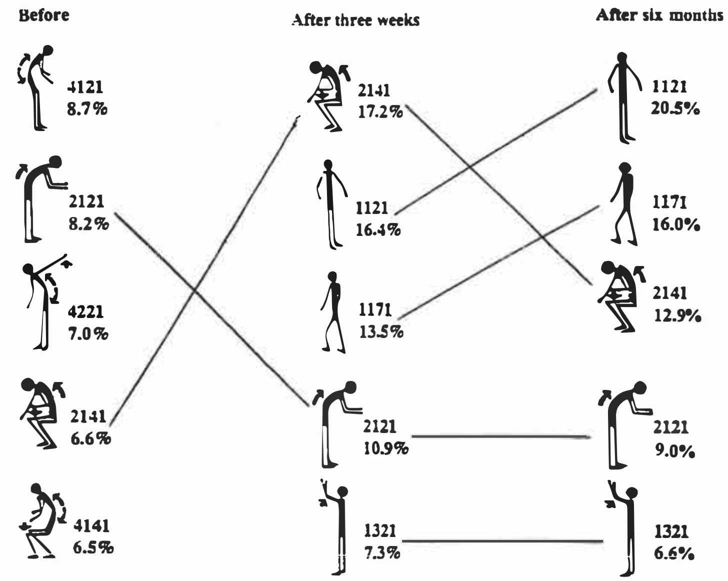

Figure 3 The five most common work posture combinations according to the OWAS classification before the course, after 3 weeks and after 6 months. The posture, the OWAS code and the percentage of observations made are given in the figure

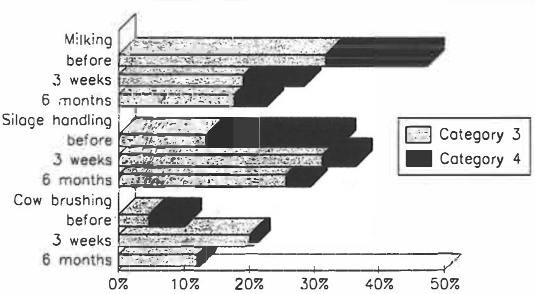

Figure 4 Percentage of the most harmful work posture combinations (action categories 3 and 4) in three work phases before the course, after the course and after 6 months

because the old movement techniques have usually been automatic for many years. Adoption of ergonomic work techniques requires motor learning, and the frequency of training is important. During the rehabilitation course the female farmers trained with the new work techniques in a classroom, then in a farm situation and after that on their own farms. The subjects all suffered from musculoskeletal symptoms, which may have increased their motivation to change their traditional work habits.

The video recordings were made during the rehabilitation course and not in the farmers' own barns in normal work situations. Thus it is not possible to say how much they used the new work techniques daily at home. At the beginning of the course and in the follow-up the subjects were asked to work with their normal daily work technique. It seems probable that the new techniques had been in active use during the 6 months, because the subjects used them in the follow-up very naturally and in the same manner as at the end of the course. It would have been difficult to change the techniques only for video recordings. In particular, the use of a milking chair when milking at normal speed would have been very difficult to do only for the camera.

The computerized OWAS method allowed efficient data collection and rapid analysis. The method was suitable for analysing postural load at agricultural work, because the work included mainly large whole-body movements. However, the estimation of weight of loads or force needed was difficult. The main principle in teaching the new way of working was to transfer the load from the back to the legs. According to the classification into OWAS categories, the new postures with bent back and both knees bent caused higher musculoskeletal load than the earlier postures with bent back and straight legs. It is for this reason that the posture combinations belonging to action category 3 were increased during the course in silage handling and cow brushing.

Improving work techniques is a long process; it demands much training and also very high personal motivation if the subject is to change old habits. It may be easier to learn improved ways of working during vocational education rather than to change old work habits. This change of work postures is one way to decrease the daily postural load and to increase the ability to work in spite of prior symptoms due to musculoskeletal disorders. Further, by developing the work tools and work environment the physical work load can be decreased in agricultural work.

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IV

Effects of occupationally-oriented rehabilitation on farmers' work techniques, musculoskeletal symptoms, and work ability

by

Nevala-Puranen N

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V

Physical strain and work ergonomics in farmers with physical disabilities

by

Nevala-Puranen N, Sörensen L

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